2021

After The Flood: Exploring The Influence Of Risk Perception And Decision Criteria Preference On Flood Mitigation In The Lake Champlain Richelieu River Basin

Emma Jane Spett
University of Vermont

AFTER THE FLOOD: EXPLORING THE INFLUENCE OF RISK PERCEPTION AND DECISION CRITERIA PREFERENCE ON FLOOD MITIGATION IN THE LAKE CHAMPLAIN RICHELIEU RIVER BASIN

A Thesis Presented

by

Emma J. Spett

to

The Faculty of the Graduate College

of

The University of Vermont

In Partial Fulfillment of the Requirements
for the Degree of Master of Science
Specializing in Community Development and Applied Economics

January, 2021

Defense Date: November 11th, 2020
Thesis Examination Committee:

Christopher Koliba, Ph.D., Advisor
Bindu Panikkar, Ph.D., Chairperson
Curt Gervich, Ph.D.
Asim Zia, Ph.D.
Cynthia J. Forehand, Ph.D., Dean of the Graduate College

ABSTRACT

In April of 2011, heavy rainfall paired with snow melt from the Green and Adirondack Mountains caused unprecedented flooding in the Lake Champlain Richelieu River (LCRR) basin. A study was subsequently convened by the International Joint Commission (IJC), and was tasked with identifying how flood forecasting, preparedness, and mitigation could be improved in order to reduce the impact of flooding in this transboundary watershed, and build the greater community's resilience to flooding. A component of this study includes an assessment of the social acceptability and political feasibility of potential flood mitigation measures, which was in part carried out through the development and administration of a survey that assessed how residents of the LCRR basin perceive risk and engage with criteria used to make decisions regarding flood mitigation.

The objective of this research is to provide insight into how members of the public in the LCRR basin consider flood risk and flood mitigation, and how those perceptions impact the feasibility of various flood mitigation measures, and can point policymakers in directions that are socially acceptable. To set the stage for the applied nature of this study, this thesis begins with an introduction to the operationalization of flood management research. That is followed by a review of relevant literature, including theories related to resilience of social-ecological systems, disaster resilience, and natural hazard risk perception. The third chapter of this thesis offers a case study of the social, political, and economic implications of the spring 2011 floods in the LCRR basin. Two articles are then presented.

The first article uses the results of a household risk perception survey (N=151) designed and administered in 2019 to primarily investigate how flood experience, adoption of flood preparedness measures, and opinions regarding flood mitigation measures impact perceptions of flood risk. Socioeconomic and geographic variables are also considered. Findings indicate that perceptions of flood risk are primarily based on prior flood experiences, rather than dependent of characteristics that make respondents more vulnerable to flooding. Additionally, there are disconnects between perceptions of flood risk and likelihood of adopting preparedness measures, and where respondents get information versus who they trust for that information.

In the second article, the results of a multi-criteria decision analysis from the same household risk perception survey are investigated. Respondents engaged with nine decision criteria, provided by the study, through ranking and scoring exercises. Results were assessed through a process called Technique for Ordered Preference Similarity to the Ideal Solution (TOPSIS), where the ranks and scores were weighted and normalized. Respondents were broken into a variety of clusters, and their ranks were assessed in comparison with other clusters. Findings indicate that respondents primarily preferred criteria which indicated altruistic outcomes from flood mitigation measures, although later rankings indicated significant variation based on demographic characteristics, geographic location, and flood experiences.

This thesis concludes with a summary, policy implications, and recommendations for future research. A further investigation into the value of flood early warning systems is provided, in addition to an agenda for exploring these concepts more deeply.

ACKNOWLEDGEMENTS

Many people are deserving of acknowledgement for their support in the preparation of this thesis. First, I would like to extend my gratitude and thanks to my adviser, Dr. Christopher Koliba, who has offered me endless opportunities to learn and explore through research that tangibly impacts the communities around us. And to the rest of our small but mighty SPE research team, Dr. Curt Gervich and Shannon Thayer- getting to know and work with you was the highlight of my research experience. Dr. Asim Zia and Dr. Bindu Panikkar were also instrumental in the development of this thesis, and in my progression as a researcher. Thank you for your time, insight, and guidance.

I wish to thank the cohort of graduate students who provided a sounding board, welcome distraction, and constant inspiration. To Conor McCracken, Kerry Daigle, Roberta Molokondov, Hannah LaCasse, Lindsay Quella, and Kati Gallagher- thank you! None of this work would have been possible without the endless support from my Burlington village. My friends who become my family, and who were raucous cheerleaders and shoulders to cry on through every step of the process, from application to defense. Klare, Chelsea, Liza, Tess- I'm endlessly grateful to you. And to Andrew, who came on the scene towards the end, but who's support was priceless and wonderfully welcome.

Finally, my inspiration in everything I do in this life is my family. I've had the pleasure of witnessing altruism, service, entrepreneurship, and selflessness in action throughout my life, and thanks are in order to my parents. Our unique experience has created three agents of change in the world, and is displayed, in part, through this work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Floods and flood hazards represent one of the most common and destructive natural hazards on the planet (Kellens et al., 2013; Botzen et al., 2009). Every year, floods claim approximately 20,000 lives, and adversely affect at least 20 million people around the world. Flood impacts are also expected to increase in coming years, due in part to the effects of climate change, as well as spatial expansion and population growth (Kellens et al., 2013). Anthropogenic activities including river regulation measures, intensified land use and forestry, and increased greenhouse gas emissions also impact the frequency and severity of flooding (Bronstert, 2003).

In 2011, the Lake Champlain Richelieu River (LCRR) basin experienced the impacts of severe spring flooding, caused by both heavy rainfall and spring snow melt, which resulted in the widespread damage of communities located within, and even beyond, the floodplains. A study was subsequently convened by the International Joint Commission (IJC), a bi-national organization established by the governments of the United States and Canada responsible for managing boundary waters between the two countries. The study was tasked with identifying how flood forecasting, preparedness, and mitigation could be improved in order to reduce the impact of flooding in this transboundary watershed, and build the greater community's resilience to flooding. A component of this study includes an assessment of the social acceptability and political feasibility of potential flood mitigation measures, which was in part carried out through the development and administration of a survey that assessed how residents of the LCRR basin perceive risk and engage with criteria used to make decisions regarding flood mitigation. Gaining an understanding of how governments and residents respond to disaster and disaster risk requires combined knowledge of the hazard, people's experiences, and their perceptions

(Fatti & Patel, 2013, p.13). The overarching objective of this work was to use these tools to gain insight into the concerns of community members towards flooding and land-use planning, and impact long-term resilience.

This thesis seeks to explore the varying perceptions of flood risk and flood mitigation, from decision-makers and key stakeholders to the public across the LCRR basin, in order to provide a clear picture of the interests and needs of the diverse communities across the region, and to increase the likelihood of successful adoption of proposed flood mitigation policies recommended to the Canadian and United States governments by the IJC.

The structure of this thesis is as follows. First, this thesis will introduce the greater IJC study and the LCRR basin, followed by a comprehensive review of literature that begins with a general look at the operationalization of flood management, and explore resilience in social-ecological systems, and risk perception and natural hazard research. The literature review chapter is followed by a case study of the 2011 floods in the LCRR basin, which investigates the ecological, social, political, and economic implications of the flood event that prompted this study.

This thesis is organized in a two-article format. The first article (chapter 4) of this thesis explores the results of the risk perception component of a household survey administered to assess perceptions of flood risk and flood management in the LCRR basin, including insight into the socioeconomic and geographic determinants of perceived flood risk, and the value of this information to the selection of flood mitigation measures. The second article (chapter 5) explores the results of the multi-criteria decision analysis component of the household survey, including the implications of public preferences on political feasibility. This thesis concludes with a chapter that delves into the greater

policy implications of this research, opportunities for further research, and conclusions drawn as a result of the preceding analyses.

1.1. Study Area

The LCRR basin is rich in natural beauty, history and vibrant communities. The basin is characterized by moderate, sub-humid continental climate, and covers an area of about 9,277 square miles. About 84% of the physical basin is contained within the United States, specifically in northeastern New York and northwestern Vermont. The remaining 16% of the basin is in southern Quebec, Canada. The LCRR basin has two types of topography. In the United States, the basin is rugged and mountainous. Many streams discharge from the Adirondack and Green mountains into Lake Champlain. At the Canada-United States border, the terrain of the basin transitions to flat plains, which extend north and encompass the entirety of the Richelieu River watershed.

Lake Champlain is roughly 120 miles long and flows from Whitehall, NY to just beyond the US-Canadian border to its outlet at the Richelieu River near Rouses Point, NY. The Richelieu River extends for an additional 78 miles north from the northernmost point of Lake Champlain at Rouses Point, NY to the south shore of the St. Lawrence River at Sorel in Quebec (International Lake Champlain Richelieu River Study Board, 2020).

Two thirds of the LCRR basin within the United States are forested. In the United States, the land cover of the basin also consists of agriculture, wetlands, and developed areas. About 2.4% of the basin is water. In Canada, the land cover is predominantly agricultural land, with some forested space. The LCRR basin supports a diverse range of ecosystems, including lake and river environments, shorelines, and floodplains. There are

also upstream communities that are primarily located along many of the tributaries that feed into Lake Champlain.

With respect to the social context of the LCRR basin, this region is the ancestral home of the Algonquin and Iroquois people. There has been record of indigenous settlements in the LCRR basin dating back 11,300 years. When European contact was recorded in the LCRR basin, the region was home to the St. Lawrence Iroquois, Western Abenaki, and the Mohawk peoples (International Lake Champlain Richelieu River Study Board, 2020).

The LCRR basin spans seven counties in Vermont, five counties in New York, and five regional county municipalities in Quebec. The estimated total population of the basin, as of 2016, is approximately 1,015,000. About 39% of the population lives in Vermont, 38% in Quebec and nearly 23% in New York.

Vermont's nominal 2017 GDP was an estimated $31.77 billion. Median household income was $55,176, the median home value was placed at $223,700, and the median rent was $886. The labor force consisted of 343,850 individuals, and the unemployment rate was 3.1%, below the national rate (Vermont Futures Project, n.d.). The most prominent industry in the state of Vermont is healthcare, where nearly 50,000 residents are employed. Healthcare is closely followed by education and retail. Other prominent industries include manufacturing, construction, hospitality, agriculture, and real estate. Tourism, recreation, and travel – particularly centered around Lake Champlain – also represent a substantial economic sector in Vermont, with direct spending by visitors often exceeding $1 billion in a year. (Vermont Futures Project, n.d.)

Additionally, there are currently nearly 2.5 million acres (1.01 million ha) of farm and forest in current use, up 24 percent since 2005 (Vermont Futures Project, n.d.).

Lakeside counties, including Chittenden and Grand Isle counties, are experiencing the greatest population increase in the state. Lakeside residences also have the highest property values in the state, which could be negatively impacted by decreased water quality in Lake Champlain.

In New York, the region within the LCRR basin is known as the North Country. This area accounts for about 2% of the state's population and largely consists of small communities with aging populations. The primary economic contributors to the region include the local universities and military bases, as well as correctional facilities. Agriculture, health care, and outdoor recreation are also important components of the North Country's economy.

Unemployment rates in this part of New York are higher than averages for the state as a whole, as are child poverty and housing vacancy rates. Many economic development initiatives are underway to prompt community-based projects meant to expand tourism, improve workforce talent, and update infrastructure, particularly within the realm of water and wastewater treatment (Office of the New York State Comptroller. 2017).

The primary region of Quebec within the Lake Champlain Richelieu River basin is the Monteregie, the administrative region in the southwest part of the province. It is characterized by its diversified economy based on a well-developed commercial sector driven by urban sprawl from Montreal, high population growth, and industry rooted in agri-food, metal products, machinery, transportation equipment, aerospace and life

science sectors, and active exporters (International Lake Champlain Richelieu River Study Board, 2020). An important economic activity in the Monteregie region is tourism, particularly concentrated around outdoor activities (both involving and separate from Lake Champlain), culture, and popular tourism-related villages (International Lake Champlain Richelieu River Study Board, 2020). A map of the LCRR basin is provided below, in figure 1.1.

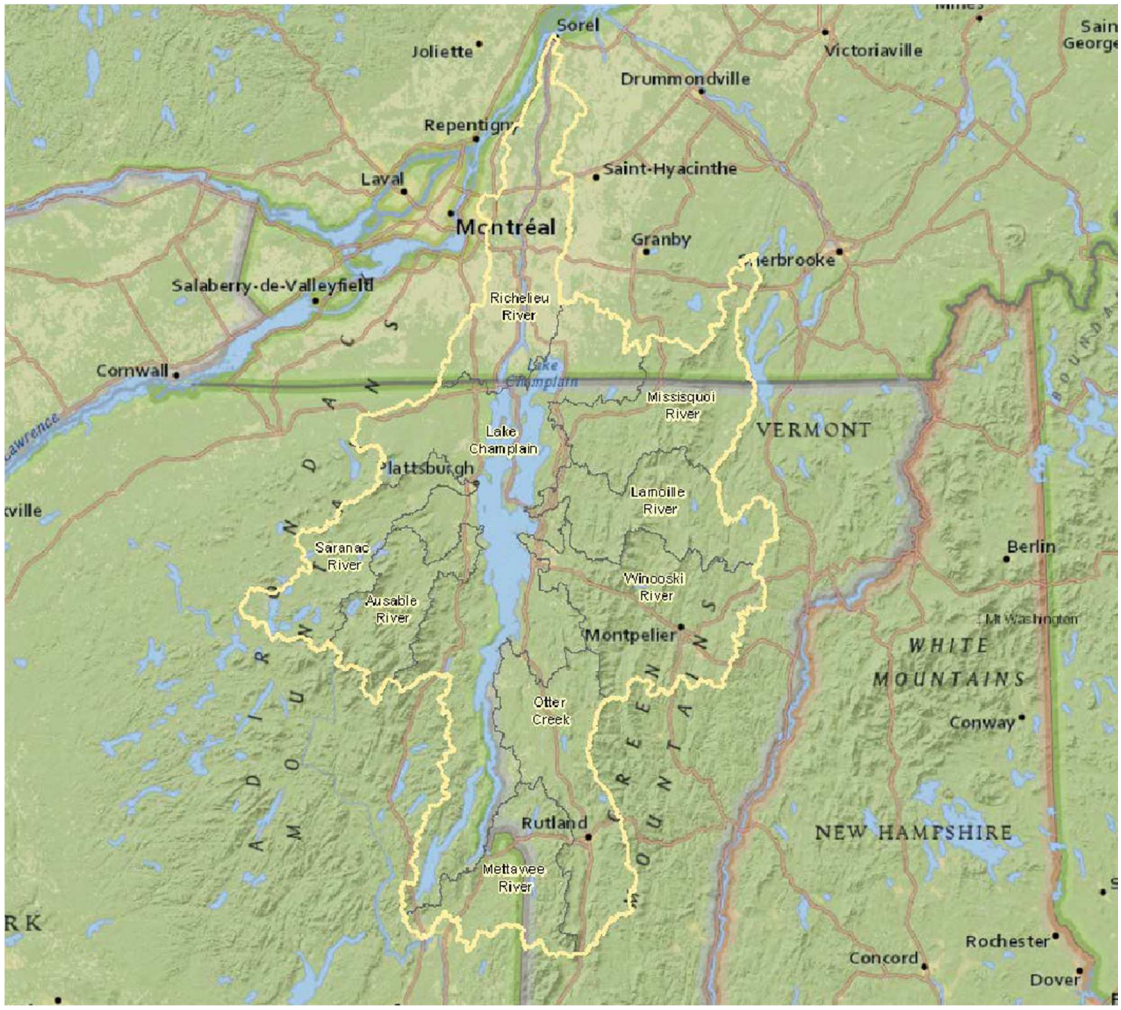

Figure 1.1. The Lake Champlain Richelieu River basin.

1.2. Study Background

Following the flooding in the LCRR basin in 2011, the governments of the United States and Canada renewed efforts to work together with state, provincial, and local governments to identify how flood forecasting, preparedness, and mitigation can be improved in the basin. In 2016, the two governments instructed the IJC to convene a study into the causes, impacts, risks, and solutions to flooding in the LCRR basin. The IJC established a study board to oversee the study and provide recommendations.

This study is a component of the third IJC Reference convened on the Lake Champlain Richelieu River basin. The first reference was convened in the 1930s following severe flooding in the basin. During that time, the IJC determined that flood control structures would be the most effective way of addressing flooding. The issue of environmental impact was raised by both United States and Canadian partners, although little action was taken on that front. The result of the reference was the construction of the Fryer Island dam, located approximately five miles downstream of St. Jean-sur-Richelieu. Construction was completed in 1939. The remedial works required to make the dam functional, however, were delayed due to the outbreak of World War II, and the work was never completed.

A second flood reference was convened for the LCRR basin in 1973 after major regional flooding. The study ultimately recommended regulation of water via a dredged channel and gated control structure in the shoal section of St. Jean-sur-Richelieu. Complications due to miscommunications led to a widening of the Chambly canal, which was carried out by Parks Canada. The ultimate response of the IJC to the report submitted in 1981 stated that:

> "Although the Commission has concluded that it is technically feasible to operate a gated structure at St. Jean that accommodates the proposed environmental criteria, the Commission was unable to determine the desirability of the gated structure and therefore is unable to make recommendations regarding the regulation of Lake Champlain and the Richelieu River. However, the Commission does recommend that a flood forecasting and warning system be instituted as soon as practicable and that flood plain regulation be implemented by the appropriate jurisdictions as a matter of urgency" (International Lake Champlain Richelieu River Study Board, 2020).

This third study of the LCRR basin has three objectives: 1) to develop a binational real-time flood forecasting and flood inundation mapping system for the Lake Champlain Richelieu River basin to help prepare for and mitigate the impacts of floods; 2) to recommend structural and non-structural measures to mitigate flooding and flooding impacts throughout the basin; and 3) to determine public, community, and stakeholder views on the desirability of the proposed measures.

The study is organized into technical working and analysis groups, a ten-member study board, a public advisory group, and an independent review group. The structure of the study's organization is displayed below:

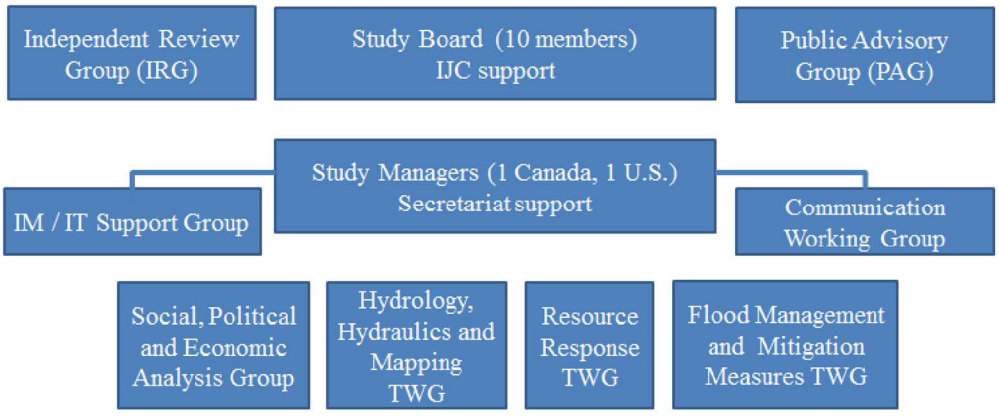

Figure 1.2. IJC Lake Champlain Richelieu River study organization.

The research carried out for this thesis is a product of the tasks of the social, political, and economic analysis group. Its primarily role is advising the study board on the complex social, political, and economic issues that form an important component of

the challenge of flood mitigation and management in a trans-boundary context. This study is the first in the IJC's history of flood studies to convene a social, political, and economic technical working group.

Ultimately, this information will inform a greater, transboundary study that has the capacity to make recommendations to the governments of the United States and Canada. A goal of this work is to ensure that those recommendations are socially acceptable and politically feasible, and the specific objectives to achieve those goals include:

- Assess the economic, social, and political responses to flooding in the transboundary LCRR basin;
- Investigate how the public across the LCRR basin, specifically in Vermont and New York, consider flood risk and what factors influence subsequent action;
- Test a model of public risk perception based on different socioeconomic and geographic factors;
- Assess how different groups within the LCRR basin prioritize flood mitigation decision criteria and consider what those outcomes mean for social acceptability;
- Compare and contrast public perception with perceptions of first responders responsible for flood management in the LCRR basin.

The results of these analyses operate within the confines of a series of flood mitigation recommendations proposed by the greater IJC LCRR basin flood study, including the following "themes":

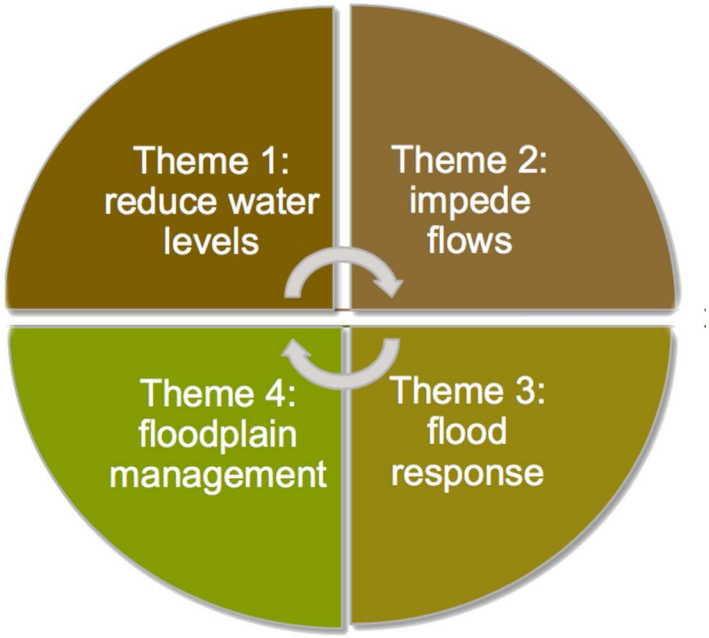

Figure 1.3. Four flood mitigation themes of the IJC study.

Theme 1 is representative of structural mitigation measures, including dams and weirs. Theme 2 considers nature-based solutions, including upland water storage and wetland restoration. Theme 3 is emergency responses to flooding, including flood forecasting and early warning systems, and theme 4 considers policy changes as a tool for flood mitigation and management.

The integration of the information collected through this study will serve in the development of ultimate recommendations of a suite of flood mitigation measures that will, ideally, consider the wants and needs of the community it will impact. A better understanding of public perceptions offers valuable insights into what is important to community members, and what is not. It also displays where gaps in capacity are, and can point this study towards options that increase individual and community resilience through a greater and more targeted spread of information.

CHAPTER 2: COMPREHENSIVE LITERATURE REVIEW

2.1. Introduction

In this chapter, an extensive review of literature and subsequent frameworks that relate to the management and mitigation of flooding is considered, with the intention of providing a holistic perspective of the impacts that flooding has on the resilience of communities, and the theories and tools that exist to assist in the building of that resilience. This chapter begins with a look at how flood management research is operationalized, followed by a review of the current status of early warning systems, which is a tool that is often used in fortifying community capacity to deal with floods and represents operationalization in action. This is followed by an examination of resilience theory, particularly within the context of social-ecological systems and the way that these frameworks are applied to transboundary systems. Particular attention will be paid to the disaster resilience of place (DROP) model as it relates to disaster and flood resilience. This chapter concludes with an investigation of the role that information regarding risk perception and decision-making play in flood mitigation and management. The frameworks and insight gleaned from this chapter contribute to the conceptual model that aided in the development of the household risk perception survey that provides the primary data for this thesis.

2.2. Operationalizing Flood Management Research

Flood risk management studies have recently acknowledged that "absolute flood prevention or protection is unattainable, which has shifted attention towards managing flood risks from a more holistic perspective" (Birkholz et al., 2014, p.13). The research components of the International Joint Commission's Lake Champlain Richelieu River (LCRR) basin flood management reference has the ultimate goal of contributing

recommendations of measures to mitigate flooding and the impacts of flooding in the LCRR basin. The role of the social, political, and economic (SPE) analysis group is to consider the avenues that would maximize the likelihood of converging toward acceptable flood mitigation measures across the transboundary landscape of the LCRR basin. This chapter will explore how the frameworks behind the research carried out in this study can contribute to policy and decision-making and yield an integrated approach to flood mitigation, as well as the transferability, strengths and weaknesses of this work within the greater context of the field.

David Elmore wrote in his 1979 text, "Backward mapping: Implementation Research and Policy Decision" that, "better policies would result, we are told, if policy makers would think about whether their decisions could be implemented before they settle on a course of action" (Elmore, 1979, p. 601). This concept, coupled with the use of evidence in promoting improvement through more effective policies and programs and how the 'work' in different circumstances (Sanderson, 2002, p.3), are paramount to this study. Throughout the conception and implementation of the research carried out for this study with respect to risk perception and decision analysis, there has been an eye towards how the information gathered could be operationalized into the development of flood mitigation policies that were politically feasible in the context of the transboundary LCRR basin. Transboundary water resources, and specifically international river basins, "pose complex and often contentious management challenges" (Akamani & Wilson, 2011, p. 409) that, "requires governing approaches, and actual policy choices, that proactively seek to enhance system resilience" in order to maintain the long-term

sustainability of transboundary social-ecological systems (Akamani & Wilson, 2011, p.411).

The introduction of a social, political, and economic (SPE) research component to an International Joint Commission flood reference represents a shift away from traditionally mandated, purely mathematical, hydrological, and ecological considerations for flood management, and towards an integrated approach to flood management with resilience as the ultimate goal. This is in line with the outcomes of the 2002 Johannesburg World Summit on Sustainable Development, where integrated water resources management was defined as, "a process which promotes the coordinated development and management of water, land, and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Rahaman & Varis, 2005, p. 15). The integration of social science research into the conclusions drawn by the other technical working groups of this project requires a consideration and operationalization of the dynamic relationships between people's values, attitudes, and understandings of the human-nature relationship on an individual and collective level, since those perceptions are reflected in natural resource management conflicts (Muhar et al., 2017, p.1).

The use of survey instruments meant to gauge public perceptions of risk and decision criteria have the goal of contributing to the policies and governance that enhance resilience in the region. There is an acknowledged challenge, though, of how to draw lessons from risk perception research to inform policy and management (Birkholz et al., 2014, p.17). One perspective is that understandings of public and decision-maker risk perception should be used to inform risk communication strategies and "thereby lessen

the societal cost of major disasters" (Birkholz et al., 2014, p.17; Burns & Slovic, 2012, p.581). A wider implication of risk perception research is the value of including perspectives from "all facets of society, not just those 'at risk', [who] have a role in shaping how risk is understood and ultimately dealt with" (Birkholz et al., 2014, p.18) and can express the role that differing perspectives and motivations can play in the political feasibility of floodplain management programs. The widespread inclusion of respondents from the entirety of the LCRR basin, including those who do not live near or in floodplains, and those who are unlikely to be impacted by floods or flood mitigation policy, provide this holistic view. Additionally, the integration of public perception information with risk perception information from decision-makers and planners will provide insight into gaps in risk communication between communities and their leaders.

Another important role that risk perception information can play in the decision-making of this study is that it underscores the importance of perceived responsibility for risk management. In the developed world, there has been a long tendency to primarily rely on large-scale, publicly funded structural protection. There is substantial desire from a governance perspective to distribute this responsibility to the household and community level, which would require long term engagement between those at risk, policy makers, and other stakeholders (Birkholz et al., 2014, p.18; Burns & Slovic, 2012; Baan & Klijn, 2004).

With respect to decision analysis, Polasky et al., (2011) notes that, "the future is always uncertain, but with global change it is highly uncertain…guidance on approaches to decision-making under high degrees of complexity and uncertainty has arisen in disparate fields, including ecology, economics, and management science," although they

clarify that, “promising approaches are often highly interdisciplinary, acknowledge and explore uncertainty, and use a combination of approaches” (Polansky et al., 2011, p. 399). Decision-making has long been aided by analyses of stakeholder preferences of decision criteria, a practice which is employed in this study. Water resource management decisions, for example, are typically guided by multiple objectives measured in a range of financial and non-financial units (Hajkowicz & Higgins, 2006, p.255). Feedback on those objectives can guide policy development, and consider how best to navigate differing priorities.

In a study carried out in Vermont to assess and evaluate the tradeoffs of the costs and benefits of design alternatives for the management of the White River Watershed, stakeholders were subjected to a multi-criteria decision analysis exercise. Stakeholders then ranked alternatives via an analytical decision framework (Hermans et al., 2007). The authors of this study noted that, “quantifying stakeholder preferences provided a focus for [decision-maker’s] discussion” (Hermans et al., 2007, p.543) and that “the development of criteria and alternatives evaluation provided a basis for future discussions, a way to operationalize the [decision-makers’] vision, and a measure of whether the vision is being achieved” (Hermans et al., 2007, p.544).

Another study carried out in Germany noted that “public and stakeholder participation in environmental planning enhanced effectiveness through improving the environmental quality of decisions and enhancing implementation” (Drazkiewicz et al., 2015, p. 211). These case studies highlighted how input from the public on decision making increased the decision-making body’s capacity to produce a decision on a watershed planning issue. Data from the household risk perception survey that deals with

respondent preferences of decision criteria provide a basis for discussion for decision-makers within the context of this work, and can guide evaluations of management alternatives from the perspectives of various stakeholders, some of which would be classified as vulnerable to flooding.

"Human behavior is the driving force underlying many resource management concerns, but is often the component that is given the least amount of attention in the development of management plans," notes Floress et al., (2015). To mediate this phenomenon, this section will explore literature that advocates for the integration of social science into environmental management, particularly with respect to flooding, in order to highlight the value of social science research within the context of the IJC flood reference.

In their article titled, "Bringing Flood Resilience into Practice," Schelfaut et al., (2011) explore flood risk management with an eye towards the development of flood resilience. They highlight how the resilience concept is seen as "a multi-disciplinary approach in which technical measures are integrated with economic, environmental, social, and governance measures" (Schelfaut et al., 2011, p.831). They also note that the participation of all stakeholders and bottom-up involvement are important factors in developing feelings of ownership of solutions, which increases resilience (Schelfaut et al., 2011).

Schanze (2006) proposes a framework for flood risk management that highlights the dynamic nature of flood risk management, with decision-making being perpetually informed by the risk components, including risk analysis and perception. This framework provides a simplified look at the diverse considerations needed for effective flood risk

management, which in many ways mirrors the structure of the LCRR basin flood reference. It requires that the various component parts of flood risk management integrate public perceptions and inherent vulnerability (Schanze, 2006, p.6) , which is data provided by the work being carried out by the SPE team.

Sustainable watershed management requires innovative institutional mechanisms that provide the awareness, interest, resources, and opportunities for stakeholders to engage in collective responses aimed at building resilience. The generation of accurate, context-specific, and policy-relevant knowledge on social-ecological systems is needed, as is multi-disciplinary and interdisciplinary collaboration between the social and biophysical sciences. A collaborative approach promises to enhance the effectiveness of the decision-making process by enhancing the quality of decisions based on the integration of dispersed knowledge and commitment of stakeholders can yield management measures. A mechanism that puts these concepts into practice is the development and execution of early warning systems. Particularly with respect to flooding, early warning systems have the capacity to open up channels of communication and integrate components of risk assessment, community governance, risk perception and ecological science that can enhance community resilience

2.3. Resilience of Social-Ecological Systems

The social ecological-systems framework was developed by Elinor Ostrom in order to consider the interactions among resources units, resource systems, governance systems, and users within a related ecosystem. The framework, Ostrom posits, “is useful in providing a common set of potentially relevant variables and their subcomponents to use in the design of data collection instruments, the conduct of fieldwork, and the

analysis of findings about the sustainability of complex social-ecological systems" (Ostrom, 2009, p. 420). Utilizing a resilience perspective to understand the dynamics of social-ecological systems is useful when considering how systems "persist through continuous development in the face of change and how to innovate and transform into new more desirable configurations" (Folke, 2006, p. 260). Cornerstones of social-ecological resilience include social learning and social memory, mental models and knowledge-system integration, visioning and scenario building (Folke, 2006).

Resilience perspectives represent a diverse expanse of considerations that vary based on the scope of the system. Since trans-boundary water systems are made up of substantial social-ecological systems, there are a variety of frameworks to employ when considering whether that system in question is resilient. The process of assessing resilience through the social-ecological systems frame is outlined by Brian Walker and David Salt in their text, "Resilience Practice: Building Capacity to Absorb Disturbance and Maintain Function." They note that a generally resilient social-ecological system is able to "respond quickly and effectively," has "reserves and access to needed resources, thereby effectively increasing the 'safe' space for operating," and "keeps options open" (Walker and Salt, 2012, p. 91). Additionally, some of the characteristics of a resilient social-ecological system are its adaptive capacity, including its "diversity, modularity, tightness of feedbacks, openness, reserves, and high levels of capital" (Walker and Salt, 2012, p. 91). With general resilience in mind, elements of the system, specifically those elements of concern (flooding, water quality, and political interactions, in the case of trans-boundary water systems) can be considered with respect to thresholds relative to the transformation of the system, and assessed within the context of the larger system

(Walker and Salt, 2012, p.105). Tools for management must utilize the general and specified resilience of the system in order to develop adaptive, effective tools.

Another prominent framework for assessing resilience is the Water-Energy-Food-Security Nexus, written by Bizikova et al., which provides a means to consider the interconnected nature of these often independently considered facets of society. Bizikova et al. outlines the means of assessing resilience through this framework through three steps. They include first understanding and identifying the "nature of the relationships among the three elements," then acknowledging the, "consequences of their changes and the changes in other sectors," and finally, understanding the, "implications for policy development and actions for addressing the three securities" (Bizikova et al., 2013, p.7). Additionally, the authors explore means of enhancing the resilience of systems through the building of awareness, which can be done by engaging stakeholders, improving policy development, coordination, and harmonization, considering governance and integrated multi-stakeholder resource planning, promoting innovating, and influencing policy on trade and investment in the environment and climate (Bizikova et al., 2013, p. 11). Their ultimate framework calls for an assessment of the Water-Food-Energy-Security system, envisioning future landscape scenarios, investing in a Water-Energy-Food Secure future, and ultimately transforming the system (Bizikova et al., 2013, p. 16).

With variables laid out for what constitutes a resilient system, particularly from the social-ecological perspective, it is important to also consider who facilitates the integration of resilience into the political and social spheres. In Lebel et al.'s piece titled, "Governance and the Capacity to Manage Resilience in Social-Ecological System," their central question is, "how do certain attributes of governance function in society to

enhance the capacity to manage resilience?" (Lebel et al., 2006). They define governance as, "the structures and processes by which societies share power, shapes individual and collective action…it includes laws, regulations, discursive debates, negotiation, mediation, conflict, resolution, elections…and other decision-making processes" (Lebel et al., 2006). Alternatively, Elinor Ostrom writes in her chapter titled, "Connectivity and the Governance of Multi-level Social-Ecological Systems: The Role of Social Capital" that governance systems are, "construed as a form of social capital that communities establish and rely on to guide human-environment interactions in a variety of settings" (Brondizio et al., 2009).

When considering how governance systems can contribute to the development of resilience, there are certain attributes that are considered to be particularly impactful to the management of resilience. Lebel et al. highlight public participation, polycentric institutions, and accountability as major components of managing resilience. Public participation, specifically through the lens of deliberation, lends to the alignment of priorities between citizens and scientists, experts, and decision-makers (Lebel et al., 2006). Polycentric institutions also play an important role in the maintenance of resilience. They are described as, "arrangements that are nested, quasi-autonomous decision-making unites operating at multiple scales…spanning from local to higher organizational levels, polycentric institutions provide a balance between decentralized and centralized control" (Olsson et al., 2006). Finally, accountability lends to the maintenance of resilience through mechanisms such as, "transparency, independent monitoring, polycentricity, separation of powers, legal resources" and have social justice as a goal (Lebel et al., 2006).

Ahjond Garmestani and Melinda Harm Benson explore some other means of achieving and monitoring resilience, with specific attention paid to panarchy as a tool for characterizing the "cross scale dynamics of social-ecological systems and a framework for how governance institutions should behave to be compatible with the ecosystems they manage" (Garmestani and Benson, 2013). Panarchy, as explained by the Resilience Alliance, is the notion that, "all systems exist at function at multiple scales of space, time, and social organization, and the interactions across scales are fundamentally important in determining the dynamics of the system at any particular focal scale" (Resilience Alliance, 2018). The panarchy framework "connects adaptive cycles in a nested hierarchy" (Resilience Alliance, 2018), and is displayed below:

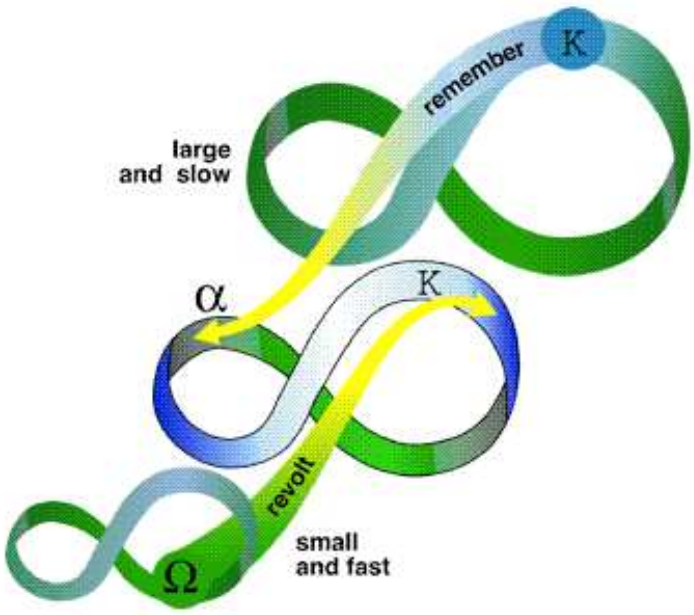

Figure 2.1. Panarchy Framework, retrieved from the Resilience Alliance (2018).

Through their framework for resilience-based governance, Garmestani and Benson explore panarchy's role in adaptive governance, noting that the panarchy model can be

used to, “reconceptualize social-ecological systems in a manner that has the capacity to better match governance to the environment” (Garmestani and Benson, 2013).

While the tools laid out as frameworks for integrating governance and resilience are often made through theoretical frameworks and conceptualizations, there are issues with the translation of these ideas into practice. Olsson et al. explores these critiques in their article, “Why resilience is unappealing to social science: Theoretical and empirical investigations of the scientific use of resilience.” They find that there are types of resilience: bounce back, bounce back and transform, and that each type has a descriptive and prescriptive capacity. They also critique how resilience theory “suggests that ‘critical changes in social-ecological systems are determined by a small set of three to five key variables’” and that a better means of creating strong foundations for resilience are to “search for integrative theories that combine disciplinary strengths while filling disciplinary gaps” (Olsson et al., 2015).

The governance of trans-boundary social-ecological systems, and in particular the governance of trans-boundary water systems are separately addressed in literature about theory and practice. Before delving into examples of trans-boundary water governance systems, there is use in acknowledging some of the principles of adaptive governance in complex systems, which has the capacity to account for the complexity of multiple governments and incongruent governance structures across political borders. In their article, “Adaptive co-management for social-ecological complexity,” Armitage et al. explore how, “building trust through collaboration, institutional development, and social learning enhances efforts to foster ecosystem management and resolve multi-scale society-environment dilemmas” (Armitage et al., 2008).

Additionally, Huitema et al. explore the notion of the "bioregional perspective" in their article, "Adaptive Water Governance: Assessing the Institutional Prescriptions of Adaptive (Co-) Management from a Governance Perspective and Defining a Research Agenda." The bioregional perspective explores first the definition of "boundaries" since they are often not explicitly clear when dealing with a basin around a body of water. They define boundaries as being, "multiple, overlapping, and often contested…drawing boundaries is the first step in determining who decides and how and with what effects. Different boundaries imply different decision makers and different effects" (Huitema et al., 2009). Due to the complexity of cross-scale interaction necessary in trans-boundary water systems, "the success of collaborations, and thus their effectiveness, depends on the availability of slack resources and stable sources of funding" (Huitema et al., 2009).

Finally, a framework for analyzing trans-boundary water governance complexes was developed by Dore et al.,(2012), as informed by the management of the Mekong Region. They establish that water governance can be understood as, "social processes of dialogue, negotiation, and decision making" (Dore et al., 2012). Their framework emphasizes the importance of drivers, which are comprised of interests, discourses, and institutions, and also utilizes arenas, context, decisions, impacts, and tools as elements necessary to analyze trans-boundary water governance complexes (Dore et al., 2012).

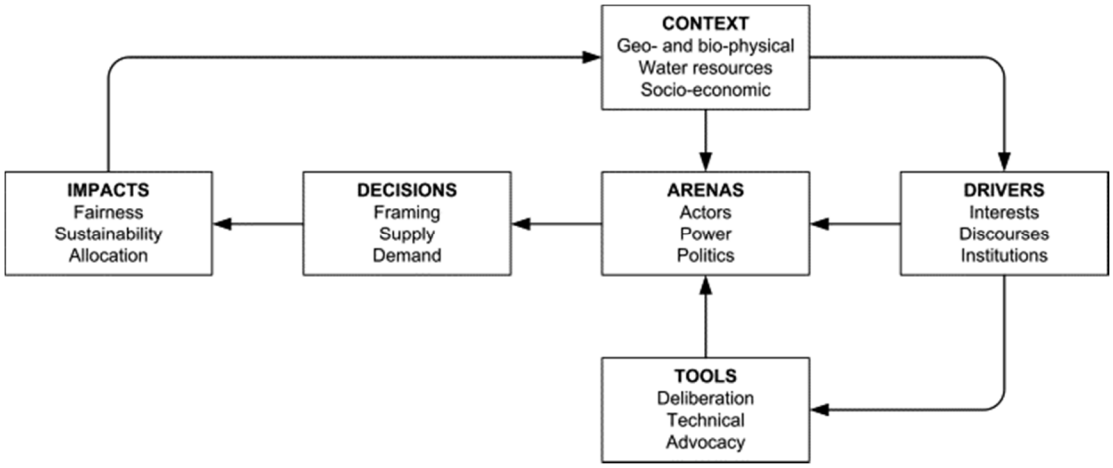

Figure 2.2. Framework for analyzing transboundary water governance complexes, retrieved from Dore et al., 2012.

2.4. DROP Model

The Disaster Resilience of Place (DROP) model was put forth by Cutter et al., (2008) in response to varying interpretations in disaster, resilience, and adaptation literature of the relationship between resilience and vulnerability. Traditionally, the conceptual linkages between resilience and vulnerability vary significantly between and within the fields of global environmental change and hazard studies, with resilience often appearing as a nested concept within larger vulnerability considerations. The DROP model, alternately, presents the relationship between resilience and vulnerability as separate but linked (Cutter et al., 2008)

The DROP model has a series of critical assumptions central to its conceptualization. It was created specifically to address natural hazards, and focuses on resilience at the community level, assuming primarily. Additionally, it is primarily concerned with the social resilience of places, while acknowledging and integrating natural and built systems into the model. Finally, the DROP model recognizes the impact that policies and events outside the scope of the community in question impacts the functioning of that community, though it is not explicitly included in the model (Cutter et al., 2008, p.602).

The DROP model acknowledges the dynamic nature of resilience and vulnerability, and begins with antecedent conditions, which include inherent vulnerability and inherent resilience, which, in the visualization of the model, overlap in an expression of their relationship as interpreted Cutter et al., (2008). The schematic representation of the DROP model can be found below in figure 2.3.:

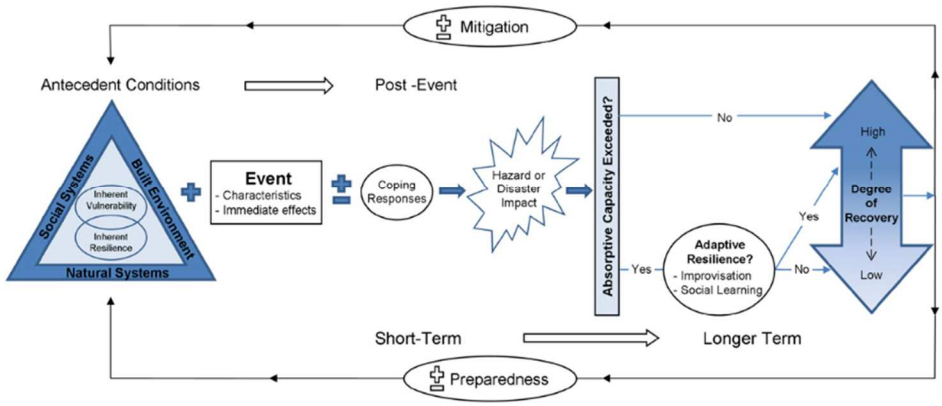

Figure 2.3. Schematic representation of the disaster resilience of place (DROP) model, retrieved from Cutter et al., 2008, p. 602.

The model also expresses the impact that socioeconomic, environmental, and infrastructural features of the community have on both resilience and vulnerability. These antecedent conditions interact with the hazard event in question to produce immediate effects, which are described by their frequency, duration, intensity, magnitude, and rate of onset. These effects are amplified by the presence or absence of mitigating actions and coping responses as designated by the community (Cutter et al., 2008, p.602)

The overall impact of a disaster is the cumulative effect of the interactions of the antecedent conditions, event characteristics, and coping responses. This impact is moderated by the absorptive capacity of the community, defined as "the ability of the community to absorb event impacts using predetermined coping responses" (Cutter et al., 2008, p.603). The absorptive capacity of a community can be exceeded if the hazard overwhelms local capacity or if the event is not exceedingly catastrophic, but the community has insufficient coping responses. If absorptive capacity is exceeded, the community can undergo adaptive resilience through improvisation, or impromptu actions that aid in recovery, and social learning, which is the enhancement of social cohesion and collective action (Cutter et al., 2008, p.603).

All of these components feed into the model's degree of recovery, which indicates the capacity for the community to bounce back from disaster. The experience that communities have with respect to their degree of recovery impacts the antecedent conditions of the community, increasing resilience or vulnerability with respect to the next disaster (Cutter et al., 2008, p.603).

Cutter et al., (2008) emphasizes the importance of measuring inherent resilience. The various types of resilience require representation in order to adequately assess a system, and as such, indicators include ecological social, economic, and institutional dimensions. Infrastructure and community competence are also included in these measurements (Cutter et al., 2008, p.604). These diverse indicators, and their integration in the model, attempt to integrate fragmented resilience and hazard mitigation literature to build out the classification of community-level resilience. Cutter et al., (2008)'s model has become a seminal work in disaster resilience literature, and has been cited over 2,500 times. The use of the DROP model in studies of building resilience to flood hazards spans from the purely theoretical in nature, to experiments that seek to consider best practices for building resilience and the evidence base for the DROP model, operationalized.

Developing the resilience of communities is recognized as critical for disaster risk management, particularly in a world where increased development and extreme weather are causing more frequent and severe disasters, and in many regions, worsening and increasingly frequent floods (Oladokum & Montz, 2019). A 2019 study seeking to measure the resilience of flood-prone communities integrated the DROP model into an operational framework for measuring flood resilience. This practice highlighted how Cutter's framework is one interpretation of the multidimensional nature of resilience, as

evidenced by the development of a model that measured flood resilience with input from the DROP model, as well as a variety of other frameworks. The integration of perception in this study was done as an important component of resilience measurement, since perceptions of flood risk from planning experts and other stakeholders were integrated into classifying hazard absorbing capacity (Oladokum & Montz, 2019).

A study that examined perceptions of urban flood risk in the global South, and particularly South Africa, contextualized the DROP model with respect to risk perceptions and hazard governance, and found that an understanding of how governments and residents respond to disaster and disaster risk requires combined knowledge of the hazard, people's experiences, and their perceptions, although that knowledge combination does not automatically increase resilience (Fatti & Patel, 2013, p.13). The consideration of the DROP model finds its use with respect to governance, which is highlighted as a barrier to flood risk management and subsequent flood resilience. The DROP model validates the author's claim that communities with low levels of resilience to disasters may be able to build resilience through effective decision-making that is rooted in experience- and perception-based knowledge (Fatti & Patel, p.13).

An additional study on flood resilience in Tehran, Iran utilized the DROP model, and more specifically, the operationalized version of the model, called "the baseline resilience indicators for community" (BRIC) framework, which allowed for the selection and testing of resilience indicators in order to gauge urban flood resilience in Tehran. A criticism of this study called into question whether quantitative measurements can adequately address the ongoing or emerging needs of local stakeholders and planning practitioners, and the need for focusing on more bottom-up and participatory

measurements in order to achieve a shared vision (Moghadas et al., 2019, p. 11). Research into perceptions of risk of residents and stakeholders would contribute important insight to this work.

In a systematic review of place attachment and natural hazard risk, the DROP model was used to display important leveraging factors for improving perceptions of disaster resilience at the local or community level, including sustainable development policies, local capacity interventions, and risk reduction strategies. Place attachment is generally defined as the affective bonds people hold towards places (Bonaiuto et al., 2016, p.35). In the context of flooding, studies analyzed in the review assessed personal and community sense of place and the way that strong or weak sense of place, coupled with understandings of risk perception, indicate resilience (Bonaiuto et al., 2016). In a study of flooding in the Italian cities of Rome and Vibo Valentia, researchers investigated the moderation effect of place attachment in the relationship between flood risk perception and coping and preventive behaviors. They found that risk perception was related to coping action, however this relation is weaker for people with greater place attachment (De Dominicis et al., 2015). Another study reviewed in this paper examined flooding in different cities in the United States. Researchers interviewed repetitive flood loss victims about their experience and asked whether flood victims with strong place attachment had more difficulty reaching a mitigation decision, and found that the importance of place makes it harder for place-attached flood victims to accept mitigation offers that cause them to relocate (Kick et al., 2011).

The DROP model, though, is not always adequately represented in flood resilience literature. In a recently released article titled, “Flood resilience: A systematic

review," McClymont et al., (2019) explore the current state of flood risk management in the context of resilience perspectives. Interestingly, the DROP model does not appear as a framework of reference for this study, nor does any work by Susan Cutter. Instead, the three primary frameworks utilized with respect to flood resilience are the engineering resilience framework, the systems resilience framework, and the complex adaptive systems framework. This is particularly interesting due to the authors' reported emergent themes regarding the operationalization of resilience, which includes context and scale, which is a significant component of the DROP model (McClymont et al., 2019).

Cutter et al., (2008) highlights the importance of including perceptions of vulnerable populations when understanding the inherent vulnerabilities within a community. They also note that improvements in risk communication, preparedness, and communication can increase social resilience, which is an antecedent condition within the DROP model (Cutter et al., 2008, p.603). Research into household risk perception of disasters, particularly with respect to flooding, have often utilized the DROP model. For instance, in a study that examined the shift from risk interpretation into responses to natural hazards, Eiser et al., (2012) explore the importance of understanding human decision-making in the face of risk as a priority for disaster risk reduction, and cites Cutter et al., (2008) as a source for considering how interacting stakeholders' respective perceptions of risks represent the development of a collective social system perspective, noting that scaling up from the individual to the societal level requires considering communities as groups of individuals who interact and communicate with one another. Those interactions contribute directly to hazard mitigation and community resilience, and the way that individuals and communities interact with one another and shape their

physical and social environments greatly influences whether vulnerability and risk are exacerbated, mitigated, or transferred (Eiser et al., 2012, p.13-14; Cutter et al., 2008).

The household risk perception study being carried out with respect to the LCRR basin contributes information about the social resilience of the social-ecological system through questions aimed at understanding perceptions of flood and other disaster risks, coupled with an analysis of demographic characteristics that would classify certain respondents as vulnerable. Additionally, the perceptions of risk of households in the basin, coupled with future data of perceptions of risk from decision makers and planners contribute to the development of a social system perspective and provide varied information regarding how risk reduction and disaster resilience programs and actions will or will not work in the region.

Generally speaking, the DROP model is an effective representation of how resilience and vulnerability dynamically impact a community's resilience to disasters. Cutter et al., (2008) are upfront regarding the limiting nature of the scale at which they operate, and the lack of ability for the model to integrate outside policies and impacts effectively. This is problematic in the context of studies that seek to classify communities that are not confined to explicit definitions. For example, the governance structures and varying cultural and social dynamics at play in transboundary social-ecological systems would prove challenging to integrate into the model.

While the DROP model doesn't explicitly outline the role of household risk perception, studies have easily integrated public perceptions into various components of the model, from household perceptions influencing inherent vulnerability, to decision maker perceptions impacting the adaptive resilience of a community.

A study that outlined an integrative conceptual framework that encompasses resilience, risk, adaptation, and transformation provides an analysis of frameworks that were identified to have conceptual weaknesses, including the DROP model. The weaknesses highlighted included the framework's inability to identify how the processes of "place-specific multi-scalar processes that occur within and between social, natural, and built environment systems" (Cutter et al., 2008, p.602) may actually build or erode the vulnerability and resilience of a community (Mochizuki et al., 2018, p. 372).

2.5. Risk Perception and Natural Hazards

In past decades, experts have been examining how flood losses can be mitigated, and have often studied risk perception as a means of managing flood risk. First, risk can be defined in this context as the likelihood and value of some possible future event, and is contingent upon the associated uncertainty that accompanies risk. A common phenomenon of uncertainty is that it leads people to depend on others to provide information (Eiser et al., 2012). The significance of understanding how residents of the LCRR basin perceive risk is that it informs components of the region's integrated flood mitigation response, including how and what to communicate to the public, where gaps in preparedness and understanding of protocol may be, and how the most vulnerable residents of the LCRR consider flood risk.

Risk perception is challenging to define, as it is influenced by many factors. When evaluating hazards with a component of risk, people tend to rely on intuitive risk judgements, or risk perceptions (Botzen et al., 2009). Some research evaluates risk perception through a cultural lens, where perceived risk reflects the social context individuals find themselves in. Other studies utilize the axiomatic measurement

paradigm, which focuses on the way people subjectively transform objective risk information, and interpret that information through the potential impact it could have on their lives (Slovic & Weber, 2002). Alternately, the psychometric paradigm considers perceived risk as a function of properties of hazards (Sjoberg, 2000). The nature of the psychometric paradigm is such that it attempts to quantify individuals' risk perceptions and attitudes through survey questionnaires, particularly through questions asked on rating scales about characteristics of risks, personal ability to cope, feelings, and attitudes. Finally, impersonal impact theory notes that, "mass mediated messages affect people's perceptions of the prevalence of certain problems or risks within a society, but do not affect their perceptions of personal risks" (Park et al., 2001, p.282). This theory posits that people tend to rely heavily on media coverage for a picture of society as a whole, but draw on personal experiences when considering their own lives (Park et al., 2001, p.282). Interestingly, Tyler (1984) does note that the influence of interpersonal relationships has a strong capacity for shifting behavior towards risk mitigating and self-protective, displaying that social networks are more effective than media campaigns, particularly with respect to personal risk judgements (Park et al., 2001, p. 282).

The quantification of these perceptions of risk allows for comparisons among specific groups in society (Kellens et al., 2013). For example, the differences in risk perception among respondents who have and have not experienced a flood can inform how they engage with flood risk, and the steps that they take to fortify their homes and belongings. Additionally, discrepancies between jurisdictions, or between the public and their decision makers can provide important insight into whether flood mitigation measures will be successfully disseminated in communities.

Determining how individuals perceive risk, as well as think about and respond to risk, is important for policy-making, particularly with respect to "providing a basis of understanding and anticipating public responses to hazards and improving the communication of risk information among lay people, technical experts, and decision-makers" (Slovic, 1987, p. 280). Sociologists often consider how risk perception can inform policy development.

In 1998, Ortwin Renn wrote in his article titled "The role of risk perception for risk management" that, "technical analysis provides society with a narrow definition of undesirable effects and confines possibilities to numerical probabilities" and "the social science perspective on risk broadens the scope of undesirable effects, includes other ways to express possibilities and likelihood, and expands the horizon of risk outcomes by referring to 'socially constructed' realities" (Renn, 1998, p.58). Incorporating risk perception, Renn notes, can identify and explain public concerns associating with the risk source, explain the context of risk-taking situations, and help articulate objectives of risk policies by enhancing fairness and institutional trust and reducing inequities and vulnerability (Renn, 1998).

The following year, Kathleen Tierney wrote in "Toward a critical sociology of risk" (1999) that there was a "need for analyzing the social construction of risks and hazards…and the framing of views people hold on hazards, and the social production and allocation of risk" (Tierney, 1999, p.219). She ascribed that risk should be assessed as a dependent variable, noting that:

> "the beliefs people hold about risk are typically used in social science to explain behavioral outcomes, such as the actions people take to protect themselves against hazards. However, such perceptions might be more usefully studied as dependent

variables, that is, by focusing on where ideas about risk come from in the first place" (Tierney, 1999, p.226).

Ultimately, the issue of natural hazard mitigation and risk management tends to rely on risk-based approaches that focus on the probability of events and the magnitude of negative consequences, or the objective risk. Risk perception provides insight into the subjective aspects of risk, the understanding of which can move disaster and risk management towards an integrated approach that seeks to build the resilience of communities to disruptions (Kellens et al., 2013).

Risk perception information manifests in governance in that "the perception of flood events has been found to change as a result of participation processes" (Wachinger et al., 2013, p. 1061) and research indicates that, "people become more aware of floods and are more motivated to initiative protective action if they are involved in a participatory process" (Wachinger et al., 2013, p.1061). Working in tandem with decision makers increases trust and also avoids creating false senses of security, which is a concept explored later in this thesis.

CHAPTER 3: THE 2011 FLOODING OF THE LAKE CHAMPLAIN RICHELIEU RIVER BASIN: A CASE STUDY

3.1. Introduction

The Lake Champlain-Richelieu River (LCRR) basin is rich in natural beauty, dynamic communities, and diverse economies. It is also a region that is vulnerable to flooding. In the past 90 years, severe floods have occurred several times in the LCRR basin. Generally, these floods were the result of a combination of rapidly melting snowpack and heavy rainfall in the late winter and spring months.

In May of 2011, the LCRR region experienced its worst flooding ever recorded – far beyond anything ever seen in the 100 years for which flood data are available. Lake Champlain water levels broke the previous historical maximum level, and the Richelieu River rose above the flood stage for more than two months. Many businesses, farms, and homes along the Richelieu River in Quebec and along the shoreline of the Lake Champlain were damaged. More than 30 communities were directly affected, and thousands of residents needed to be evacuated. Damages were estimated at more than $90 million. It was an event that had extreme impacts on the basin's people and ecosystems, and has prompted the study of flood mitigation measures that will ensure a flood of that nature will never impact the LCRR basin as substantially again (International Lake Champlain Richelieu River Study Board, 2020). The consequences of the spring 2011 floods in the LCRR basin has had a lasting impact on the economic, social, and political aspects of life in the region. This report will act as a case study for the differentiated effects of flooding, and this flooding event in particular, in order to present a diversified, interdisciplinary look into the vulnerability the region has to flooding. Literature and evidence will interact to provide a contextualized look at how

flooding has impacted the region. The report will conclude with a brief examination into different themes of flood mitigation that are potentially feasible for the LCRR basin.

3.2. Economic Impacts of Flooding

From a financial standpoint, floods are responsible for 20-30% of economic losses caused by natural hazards worldwide. The widespread impact of flooding can largely be attributed to anthropogenic interference in riverine systems, namely floodplain development and interventions with respect to river movement and drainage (Douben and Ratnayake, 2006). The economic effects of flooding can be examined in four ways, including direct, indirect, tangible, and intangible impacts. Direct effects occur as a result of flood water coming into physical contact with humans, property, or other objects. Indirect effects are "induced by direct impacts but occur - in space and time- outside the flood event" (Merz et al., 2010, p. 1698). Whether or not the effect is tangible or intangible is tied to its ability to be specified in monetary terms (Merz et al., 2010). This section will primarily examine the economic impact of flooding on varied sectors of society, and how those economic impacts came to fruition in the LCRR basin.

Merz et al., classify various elements at risk during flooding events according to economic sectors, which is replicated below:

Table 3.1. Classifications of elements at risk from flooding according to economic sectors.

Sector	Example	Remarks
Private households	Residential buildings including contents, garages, summer houses, etc., privately used vehicles	Majority of data sets and approaches exist for this sector. Variation of assets and susceptibility is rather low compared to other sectors.
Industry, manufacturing	Mining, metal processes, car and mechanical engineering industry, chemical industry, construction industry, installers workshop, carpentry, etc.	High variability and little data available. Transfer of asset values and damage functions within sector is problematic. Booysen et al. (1999) argue that it is not possible to develop a standard damage function for industries and that questionnaires have been provided for each industrial plant.
Services sector	Retail trade, wholesale trade, credit and insurance institutions, hotel and restaurant industry, lawyers, software companies, etc.	High variability and little data available. Transfer of asset values and damage functions within sector is problematic.
Public sector	Education and culture (schools, universities, theaters, etc.), recreation and sports (campsite, sports hall, etc.), administration, health care and social welfare (hospitals, nursing homes, etc.), churches	High variability and little data available. Transfer of asset values and damage functions within sector is problematic.
Lifelines and infrastructure	Water supply, sewerage, and drainage, gas supply, power supply, telecommunication, transportation	Little data available. Transfer of asset values and damage functions possible with certain classes, e.g. unit values and damage functions for roads of certain characteristics.

Agriculture	Loss of crops, damage to buildings, contents, machinery; soil erosion, loss of livestock	Methods and data availability comparatively good. Average values per element at risk might be suitable in countries where this sector has a small damage potential compared with other sectors.
Others	Damage to flood defense structures; clean-up costs, evacuation and disaster management costs	Little data available. Average values are often used, e.g. average costs of evacuation (Penning-Rowsell and Green, 2000), but do not hold in the context of multiple hazards (Pfurtscheller and Schwarze, 2008).

Note. Reproduced from Merz et al., 2010, p. 1703

In a paper titled, "Characteristic data and on river floods and flooding; facts and figures," Douben and Ratnayake (2006) explored the economic impact of flooding across the world, noting that:

> "The escalation of severe flooding events is increasingly posing a substantive threat to both sustainable development and poverty reduction. The associated increase in reconstruction costs and loss of development assets has forced the issue of disaster reduction and risk management on various policy agendas. Building and maintaining resilient societies by developing a culture of prevention and preparedness is an important step in flood mitigation of least developed, emerging as well as developed countries" (Douben & Ratnayake, 2006, p. 22)

One of the major economic impacts of flooding is the effect of flooding on private homes, including movable items, privately used vehicles, and building materials (Merz et al., 2010). In order to quantify the impact of flooding on residences, the utilization of flood damage curves is essential. Flood damage curves for residential structures rely on base data derived from incidents of damage or surveys of potential damage. Damages can be classified as either structural or content related, and typically for households, estimates are refined based on demographic and household characteristics, including number of

people (and adults) in the household, family income, and years of residence in the home. This data is coupled with information regarding flooding events. Flood damage curves can be initially developed by utilizing data from the levels of worst historical flooding, flood type, and flood velocity (McBean et al., 1988). As a tool, they can be utilized to estimate potential flood damages, and often, flood policy is built around the potential for damage to residential and commercial structures based on historical flood data (Smith, 1994).

Another consideration of the economic impact of flooding is the effect it has on the local industry and small businesses. To use the LCRR basin as an example, Vermont's top five industries as a percent of total Gross Domestic Product in 2017 are finance, insurance, real estate, rental, and leasing (21%), government and government enterprises (15%), educational services, health care, and social assistance (13%), professional and business services (10%), and other (34%) (Bureau of Economic Analysis, 2017). Further, in terms of revenue generated, Vermont's top five agricultural products are dairy products, beef cattle and calves, greenhouse and nursery products, hay, and maple products. Additionally, hotels and ski resorts make up a large component of the state's economy (NetState, 2018).

New York State, which is more diverse in population and industry, classifies the state by ten distinct industry clusters. The Lake Champlain Richelieu River basin falls into the North Country industry cluster, which is primarily the largest employment gains in the North Country in 2014 were recorded in professional and business services, and trade, transportation, and utilities. Travel and tourism also rank among the five largest

clusters in terms of employment across the State of New York and has the most employment of any cluster in the North Country (New York States, 2014).

Small businesses make up 99% of businesses nationwide in the United States, and are "extremely vulnerable to natural disasters and 25% never reopen following a major disaster" (Davlasheridze and Geylani, 2017, p. 865). A case study conducted on factors affecting business recovery immediately after Hurricane Katrina found that typically, post-disaster industrial recovery was defined by either business sector, size, and building occupancy (Chang and Falit-Baiamonte, 2002; Sydnor-Bousso, 2009), amount of operations disruption, and general economic decline (Tierney, 1997), or business size, whether the business property is owned or leased, and prior disaster experience (Dahlhamer and D'Souza, 1995).

In the LCRR basin, recreational activities surrounding parks, as well as natural features like lakes and rivers, make up a substantial component of the local economy. In an International Joint Commission study conducted with respect to the trans-boundary Lake Ontario and St. Lawrence River, the economic impact of changing water levels was assessed. Natural hazards that affect bodies of water and the surrounding areas contribute to lower purchases of sporting and fishing licenses, reduced service and closure days at marinas, reduced service, closure days, and reduced attendance at state parks and campgrounds, and the burden of repair costs if these locations do not have proper insurance or adaptation expense preparedness (Connelly et al., 2005). Each of these considerations illicit potential performance indicators for industry in the LCRR basin. Other considerations with respect to the effect of flooding on economic activities include effects exacerbated by climate change, including changes in "energy supply

(hydropower), tourism (snow, water usage, glaciers), forestry and agriculture (productivity changes with changes in water supply, need for irrigation) and services from natural and semi-natural ecosystems" (Beniston, 2009, p. 295).

Small Business Administration (SBA) loans can be provided to homes and businesses to manage and facilitate repairs and replacements to personal and business property following natural disasters. In Vermont, the spring 2011 floods witnessed the filing of 54 SBA loans for homes, and 20 SBA loans for businesses. In New York, 7 SBA loans were made for homes, and 8 SBA loans were made for businesses.

Federal Emergency Management Agency (FEMA) data for public and individual assistance is available for the spring 2011 floods in New York and Vermont. Cost and damage information is replicated below, and represents the costs that households, municipalities, and states required coverage for following the spring flooding event of 2011. This also encompasses damage to infrastructure and public services.

Table 3.2. FEMA individual assistance in VT and NY.

FEMA individual assistance in VT		
Total residences impacted	Overall	250
	Destroyed	25
	Major damage	73
	Minor damage	123
	Affected	29
Percent uninsured residences	5%	
Percent low income households	47%	
Total individual assistance cost estimate	$2,645,322	
FEMA individual assistance in NY		
Total residences impacted	Overall	1,060
	Destroyed	14
	Major damage	218
	Minor damage	342
	Affected	486

Percent uninsured residences	24.7%
Percent low income households	39%
Total individual assistance cost estimate	$5,384,024

Note. Retrieved from Federal Emergency Management Agency, 2018.

Table 3.3. FEMA public assistance in VT and NY.

FEMA public assistance in VT	
Primary impact	Damage to roads and bridges
Total public assistance cost estimate	$793,753
Statewide per capita impact	$1.30
Countywide per capita impact indicator	$3.27
FEMA public assistance in NY	
Primary impact	Damage to roads and bridges
Total public assistance cost estimate	$38,610,718
Statewide per capita impact	$2.03
Countywide per capita impact indicator	$3.27

Note. Federal Emergency Management Agency (2018) Articles: Vermont Severe Storms and Flooding (DR-1995) and New York Severe Storms, Flooding, Tornadoes, and Straight-Line Wind (DR-1993).

The costs and damages from the flood in the United States were most significant on the New York side of the LCRR basin. Infrastructural damage proved to be the primary impact in both Vermont and New York, although the cost was substantially higher in New York. Additionally, far more homes were damaged in New York than Vermont.

In Quebec, the equivalent of FEMA public assistance is the Canadian Disaster Financial Assistance Arrangements (DFAA). In April of 2011, the DFAA provided $81,612,000 in assistance to communities in the Monteregie region, and aided in the evacuation of 1,651 people. In the Southern Quebec region, the DFAA spent an additional $13,064,000 and aided in the evacuation of 1,000 people. The breakdown of federal disaster response costs for the spring flooding of 2011 is as follows:

Table 3.4. Federal disaster relief costs for LCRR spring 2011 flooding.

Region	Federal Cost
Vermont	FEMA: $3,439,075
New York	FEMA: $43,994,742
Quebec	DFAA: $94,676,000

Note. Retrieved from the following sources: Federal Emergency Management Agency. (2018). New York Severe Storms, Flooding, Tornadoes, and Straight-Line Wind (DR-1993); Federal Emergency Management Agency. (2018). Vermont Severe Storms and Flooding (DR-1995); Public Safety Canada. (2018). Disaster Financial Assistance Arrangements (DFAA).

The economic impacts of floods is widespread, as evidenced by the spring floods in the LCRR basin. Additionally, the economic impacts highlighted here leave out the intangible impacts of flooding, which likely makes the dollar amount of damage much greater. The economic data from this flooding event also highlights the disproportionate impact that flooding had across the LCRR basin, with exacerbated damages concentrated in Canada. This is further explored through the social impacts of flooding.

3.3. Social Impacts of Flooding

An individual's level of connection to their neighbors and community has significant implications for how well that person will be able to recover from the impacts of flooding (Banks et al., 2016; Bei, 2013, Carroll et al., 2010; Jones et al., 2011; Wilson, 2012; Wind & Komproe, 2012). A recurring theme throughout the literature reviewed here is the importance of the social capital of a community to its ability to respond effectively to disaster, and this is reiterated by the effect on media from the LCRR flooding event of 2011.

An additional component of importance in assessing the impact floods have on social life are the capacity of the community, such as the responders, both volunteers and working professional, that are heavily relied upon post-flooding event. Cutter et al., (2008) described the availability of counseling and support services to be part of the community's competence, hence strengthening its overall resilience. Workers employed in social support sectors are likely to be in high demand after a flood event, and as a result will work longer hours and often neglect their own mental health and physical health (Carroll et al., 2010). Studies of flood first responders have shown that relying on help from outside the community can help to temporarily relieve the heavy burden upon people impacted to also be responsible for providing relief (Carroll et al., 2010). These factors underscore the importance of fostering social connections, a theme continuously highlighted throughout the literature (Carroll et al., 2010; Cutter, et al., 2008; Wilson, 2012).

The demographic factors of a region also play an essential role in understanding the level of vulnerability and resilience of that community or region possesses. Key demographics include the characteristics of the general population and the characteristics of households within the community or region. Population characteristics help to conceptualize the types of individuals that would be at greatest risk in a flooding event. One of the most common indicators found within the risk assessment literature is education level, as it has been repeatedly shown that there is an inverse correlation between education level and negative flood impacts (Banks et al., 2016; Abbas & Routray, 2014). Age is another important factor in flood resilience. Elderly populations

and children are the most at risk from impacts of natural disasters (Ajibade et al, 2014; Bei, 2013).

There are also population characteristics that bridge the social and economic domains. Local rates of unemployment give insight into a community's ability to absorb natural disaster impacts (Peek-Asa et al, 2012). Poverty rates have economic implications that identify particularly vulnerable individuals, but also it has been illustrated that this characteristic can be offset by social connectivity and involvement in local faith-based organizations (Banks et al, 2016). All of these factors are dynamic and will help to shape the social fabric of a community. Understanding the status of the tenancy of the household indicates vulnerability. Renters have less control over their particular housing situation, typically possess fewer resources, and often have less robust insurance coverage than homeowners (Abbas, 2014).

Public health can be considered in the context of two broad categories: physical and mental health. Generally, impacts of flooding upon populations are calculated using only mortality rates (Fewtrell & Kay, 2007). This tactic does a disservice to the other ways in which populations suffer, including short-term and long-term physical health impacts (Alderman et al., 2012). Additionally, a focus on the mental health impacts of flooding is important for understanding overall flood impacts on the social fabric of communities.

The most immediate and apparent short-term impact on human health as a result of a flood event is death by drowning, followed by individuals who suffer traumatic injuries as a result of the event (Alderman et al., 2012; Carroll et al., 2010). Additionally, demographic factors can drive health impacts; individuals that are unprepared and often

unaware that they live in a floodplain are more likely to suffer traumatic injuries and be exposed to waterborne illnesses (Alderman et al., 2012; Abbas & Routray, 2014; Carroll et al., 2010). These immediate health impacts can be mitigated through education and early warning systems.

The severity and duration of a flood have several impacts in both short and long-term human health. In the short term, people exposed to fecal matter in flood waters can develop gastrointestinal infections, respiratory infections, and skin rashes (Abbas & Routray, 2014). The risk of exposure to effluent increases with the use of septic systems and lengthy disruptions in the availability of drinking water (Abbas & Routray, 2014). There is also an increase in bug bites and stings and exposure to disease carried by rodents (Cox et al., 2008). fold decrease in their health outcomes as a result of the disruption (Alderman et al., 2012).

Households that have had flood waters penetrate homes are at risk of various health issues that can occur for prolonged periods after the initial flooding event. Respiratory and skin infections can occur in individuals once they return to their homes if they are unaware of proper cleanup or disposal methods. Carroll et al., (2010) found that when people were cleaning, they were unaware of what was safe to keep and what should be disposed of, leading to outbreaks of respiratory infections within the community. Further, it is believed that rodent and mite infestations contribute to the development of skin rashes and respiratory complications in individuals whose homes were inundated (Alderman et al., 2012).

Mental health is another aspect of public health that is important to consider when trying to get a complete picture of the impacts of flooding on the populations within the

LCRR basin. Floods can have a myriad of impacts on psychological health. It is critical to ensure that, following a flooding event, all individuals impacted by a flood have access to counseling and other supports, but also that there is a focus on individuals who have pre-existing conditions, both physical and psychological as they are more vulnerable to developing anxiety, depression, and PTSD (Banks et al., 2016; Paranjothy et al., 2011; Tapsell & Tunstall, 2008).

One of the main complications with flooding is that it disrupts an individual's daily routine which causes distress (Bei et al., 2013). Although the magnitude of disruption needs to be considered, awareness of that factor alone can help disseminate appropriate emergency responses to flooding and ways to mitigate the damage they cause. There is evidence of the taxing mental strain caused by evacuation, as the uncertainty of the safety of their home and possessions put people under a vast amount of stress (Paranjothy et al., 2011). After an evacuation, the length of displacement and the conditions under which people are housed while they are unable to return to their homes are important things to consider (Banks et al., 2016; Bei et al., 2013; Carroll et al., 2010: Paranjothy et al., 2011: Tapsell & Tunstall, 2008). Mental health is significantly impacted by separation from one's possessions and home (Carroll et al., 2010; Paranjothy et al., 2011) and this impact is compounded when those individuals are of low socioeconomic status, are elderly, or both (Banks et al., 2016; Bei et al., 2013).

Similar to physical health, individual factors play a large role in the development of mental health concerns. Low education and socioeconomic status impact an individual's ability to prepare for and cope with flooding, as they amplify impact. When considering socioeconomic status, several factors play into this vulnerability. Individuals

with lower household income are less likely to have prepared for an event and will have a harder time recovering after (Banks et al., 2016; Ginexi et al., 2000; Lamond et al., 2015). Lower-income earners are also more vulnerable to job disruptions and job loss that can occur due to flooding because they have less financial security (Peek-Asa et al., 2012). Difficulty in recovery occurs not just because of lower availability of financial resources but also because of a lower likelihood that individuals with lower incomes are also less likely to have purchased flood insurance (Banks et al., 2016). Insurance companies are also a source of stress that can lead to individuals feeling anxious, depressed, and hopeless, drawn-out disputes with unclear resolutions can have a significant impact on an individual's ability to cope with the losses suffered in a flooding event (Carroll et al., 2010).

A preliminary component of the social, political, and economic analysis group's assessment of the social impact of flooding was a review of relevant media related to the spring 2011 flooding in the LCRR basin. The press review was carried out through the use of the Nexis Uni Database, which allowed for the scanning of news sources through the use of keywords. The key search term used was "Lake Champlain Richelieu River Flood 2011", which yielded 466 relevant articles. Each article was coded in a spreadsheet, with attention paid to the following elements: news source, country, region (state or province), and date of publication. Articles were reviewed for content, and coded accordingly. Each article was coded for a specific set of vulnerabilities and assets common to studies of community resilience. In developing a coding framework, Geoff Wilson's "capitals framework" guided the work, as it allowed for the best conceptualization of community resilience and vulnerability (Wilson, 2012) These

capitals were utilized in initial explorations of article content in the media review. A table addressing the capitals and their uses can be found in table 3.6., below. As public health was a crucial impact of the spring flooding, that was considered as a category as well.

Table 3.5. Community resilience capitals and indicators.

Capital	Definition	Examples of Indicators
Economic	Financial resources that are available to a community, for either public or private investment.	• Diversified Individual income streams • Poverty/Debt • Diversified business types • Net imports of food/goods • High dependence on external funds • Over dependence on agriculture/primary production
Social	The presence of social networks within a community, specifically the relationships that exist between people and groups of people.	• Ability to rely on neighbors • Availability of skills training/education • Out migration of young people • Service deserts • Lack of control of community destiny • Good health and sanitation • Low levels of corruption
Environmental	The natural resources available to a community including both natural capital and "biocapacity" of the community's surrounding environment.	• High levels of biodiversity • Predictable agricultural yields • Soil quality/soil management practices • Size of carbon footprint • Localized energy supply • Desertification • Salinization

Note. Retrieved from Wilson, 2012, p.21-29.

An initial scan allowed for the identification of articles of certain topics, such as those addressing Canadian vs. American experiences, as well as the impacts of the flood on specific aspects of community life. A smaller number of seminal articles were selected for deeper dives, in which Wilson's list of capital assets and vulnerabilities were used as codes.

Certain articles were analyzed and further explored for the value of their narrative within the context of the IJC study, specifically with respect to gaining insight into the community experience associated with many of the ecological and natural hazards being explored. These brief vignettes are provided below:

An article by The Guardian that covered Canadian flooding in 2011 displayed photographs of homes and businesses in Quebec, taken first in June of 2011, during the floods, and then again in October of the same year. The Guardian interviewed a resident named Michel Huneault, who noted how "we have an ambiguous relationship with bodies of water. We are drawn to live near them, yet know them to be unpredictable" (Booth, 2013). The article, which expressed the region's quick response to flooding, highlighted how social ties grew stronger as neighbors look out for one another, and the communities rallied into teams of volunteers to sandbag, distribute provisions, and, as the waters receded, clean up debris (Booth, 2013).

An article published April 12th, 2012 titled, "After a Disastrous 2011, Quebec Farmers Wonder what's in Store for '12" by Canwest News Service described the impact the 2011 flooding of the Richelieu River had on the agricultural community in the Richelieu Valley. They note how 200 farms exist along the river, and nearly all of them

were impacted by the spring floods. The flat river plains make for a vulnerable agricultural landscape, and waterlogged soil delayed or prohibited planting on many farms, which primarily grow corn, soy, and hay. This article highlighted the particular struggles of the Bisaillon and Guay Farms. Bisaillon Farm, located west of the Richelieu River, had flooded land that took until the end of June to dry, delaying seeing. Unseeded land cost the farmers $18,000 in damages, $8,000 of which was compensated by a special Quebec fund for farmers. Guay's farm, which is east of the Richelieu, also had submerged fields, and late seeding cost the farm $75,000 (Canwest News Service, 2012).

Several articles that addressed the flooding in Vermont in the spring of 2011, though fairly sparse, primarily covered the "slowly unfolding catastrophes on island communities along the lake," which, although detrimental, had no casualties or mandatory evacuations. The narrative of flooding in North Western Vermont is characterized by road closures, private well contamination, and costly public infrastructure damage. One Burlington resident included that "I was told I didn't need flood insurance when I bought this house. I have no coverage for this" (Associated Press, 2011).

Stories of devastation were widespread throughout the press review and were concentrated on the communities along the Richelieu River that experienced the brunt of the flooding. 1,000 residents were forced to evacuate their homes, and 3,000 homes experienced damage. Articles describe the challenges faced by residents, including over four weeks of ongoing flooding and the mental health implications of damaged homes and shattered lives. They tell of how military and trained counselors were deployed to provide relief to residents. One resident told Canwest News Services about how, "After

so many days, it gets to you...we're at our wit's end...I'm a volunteer firefighter, and I filled probably 1,500 bags of sand in just that first week. It doesn't look like it will go down for at least another month...we just don't talk about it if we can help it" (Canwest News Service, 2011).

An article by the Associated Press covered the tribulations of flooding in Colchester, VT, on May 29th, 2011. It was one of the few articles in the press review that explored the impacts of flooding in Chittenden County, VT. The article notes how residents felt lucky compared to other disaster areas in the country, citing Mississippi and Alabama, and not the Richelieu River downstream. Residents noted that the flooding led to the disruption of daily life, streets covered in flood water, and the toll that the flooding took on residents. One resident, Bryan Ducharme, had no running water for about a month, which took a toll on him, mentally.

Each instance highlighted the qualitative, human impact that flooding had on the region, and provided a storytelling component to the often quantitatively assessed disasters. This also sets the stage for the importance of considering public preferences and perceptions in the development of flood mitigation measures.

3.4. Political Impacts of Flooding

Damage to components of public infrastructure pose challenges for local, state, regional, and national communities. With respect to the flood impacts on roadway transportation, Taylor and D'Este (2007) explain the difference between network reliability and vulnerability. The difference, they write, is that "vulnerability is more strongly related to the consequences of link failure, irrespective of the probability of failure…while reliability focuses on connectivity and probability" (Taylor & D'Este,

2007, p. 13). The authors then explore a series of questions useful for, "determining how well a transport system would perform when exposed to different kinds and intensities of disturbances," (Taylor & D'Este, 2007, p. 13) which include exploring how interruptions of different critical links affect system performance, how network performance is affected by general capacity reductions, and how the system is affected by variations in travel demand (Taylor & D'Este, 2007, p. 13-14).

The economic impact on residential and industrial sectors raises the question of examining the subsequent impact of flooding on the larger critical infrastructure systems within communities of interest. Measuring an area's resilience to disaster involves a look into the "lifeline systems" that influence public welfare and economic prosperity. Comes and Van de Walle (2014) define critical infrastructure by their "physical components [road networks, hospital buildings], and services that are provided via these components [transportation of passengers or goods; health care]" (Comes & Van de Walle, 2014, p. 190). The United States Department of Homeland Security recognizes 16 critical infrastructure whose:

> "assets, systems, and networks, whether physical or virtual, are considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof" (United States Department of Homeland Security, 2018).

A framework for managing resilience in infrastructure systems produced by McDaniels et al., (2008) highlights the aspects of recovery and planning that contribute to resilience. Those factors include the socio-technical context pre-disaster, planning, vulnerability, hazards, robustness, adaptation, rapidity, and learning (McDaniels et al., 2008, p. 314). More recently, the notion of critical infrastructure as a component of

national security has become prominent in federal rhetoric, due to, "the economic prosperity, military strength, and political vitality of the United States all depend[ing] on the continuous functioning of the nation's critical infrastructures" (Collier & Lakoff, 2008, p. 2). Critical infrastructure within the context of natural hazards and disaster planning is examined through the context of hurricane management in Florida in Bigger et al's (2009) article, "Consequences of critical infrastructure interdependencies: Lessons from the 2004 hurricane season in Florida." They note how:

> "The integrity of critical infrastructures is at risk worldwide not only because of the growing frequency of extreme events of natural causes, but also because they are increasingly vulnerable to local disturbances. This is, in part, due to the strong reliance of critical infrastructure on each other, which may turn a local disturbance in one of them into a large scale failure via cascading events that have catastrophic consequences on society as a whole" (Bigger et al., 2009, p. 201).

Identifying the critical infrastructure networks of communities of interest, particularly place-based communities affected by natural hazards, require the identification of root causes of failures, infrastructural dependencies, and failure impacts (Bigger et al., 2009, p. 205-208).

Several lessons can be gleaned from the management of past natural disasters and their impact on social, political, and economic realms of the affected and peripheral communities in the United States. With respect to the policy shifts that often accompany natural disasters, much of the more recent literature addresses the case study of Hurricane Katrina. Though previously mentioned in other sections of this literature review, the policy lessons from this focusing event prove useful in considering how to prompt change within the realm of disaster planning and emergency management.

Raymond J. Burby wrote in the article "Hurricane Katrina and the Paradoxes of Government Disaster Policy: Bringing About Wise Governmental Decisions for

Hazardous Areas" about the two paradoxes that inhibit progressive urban development and envelop communities in cycles of "ever more catastrophic losses from natural hazards" (Burby, 2006, p. 173). The two paradoxes he describe are the "safe development paradox," because government policies make hazardous areas targets for catastrophe in their attempt to make said areas safe for development, as well as the "local government paradox," which occurs as a result of local public officials causing citizens to bear the brunt of losses in disasters due to their failure to take actions necessary to protect them (Burby, 2006, p. 172). Burby attributes these paradoxes to "the wholly predictable outcomes of well-intentioned, but short-sighted, public policy decisions at all levels of government" (Burby, 2006, p.172). The Brookings Institution's Metropolitan Program explores the causes of the two paradoxes by addressing how:

> "Federal policies and investments in flood protection facilitated development in dangerous locations…and failed to discourage floodplain development…The traditional federal deference to state and local land-use planning has meant that federal spending on levees and other protections has been unaccompanied by sensible restrictions on subsequent construction…at the same time, the availability of subsidized federal flood insurance for new development in flood plains…also represents a failure of Washington to take the lead in discouraging communities from building in harm's way" (Brookings Institution Metropolitan Program, 2005, p.23-25).

Burby provides a series of recommendations to mediate the problematic use of local and federal policy to deal with disasters by addressing the Flood Insurance Act, which he states could "be amended to add the preparation of local comprehensive plans with hazard mitigation provisions as a condition for continued participation in the program" (Burby, 2006, p.185). In the state of Vermont, the development of municipal

hazard mitigation plans is currently the precursor to enrollment in the National Flood Insurance Program (Vermont Emergency Management, 2018).

Disaster losses, beyond policy failures, can be attributed to the interactions between three major systems:

> "the physical environment, which includes hazardous events; the social and demographic characteristics of the communities that experience them; and the buildings, roads, bridges, and other components of the constructed environment. Growing losses result partly from the fact that the nation's capital stock is expanding, but they also stem from the fact that all these systems- and their interactions- are becoming more complex with each passing year" (Mileti, 1999, p.3).

The primary influences on these systems in the United States, Mileti continues, is the constantly changing physical systems on earth, the recent and projected demographic composition and distribution of the United States population, and the growing density of the built environment, including public utilities and transportation systems, which makes the potential losses from natural forces larger (Mileti, 1999). Gerber (2007) notes that, "certain key deficiencies in US disaster management result from institutionally induced incentives" (Gerber, 2007, p.236), meaning attempts to promote better mitigation practices actually increase potential disaster losses.

These influences, as well as the trouble presented by short-sighted policy development, is emphasized in a case study on Hurricane Katrina and its capacity to be utilized as a focusing event for policy change. Gerber (2007) explores the various obstacles to effective policy making, including organizational (e.g. FEMA's move into the Department of Homeland Security), institutional (e.g. US federalism creates important policy goal and incentive incongruities between levels of government), and behavioral (e.g. Americans do a fairly poor job of individual preparedness for emergencies/disasters) (Gerber, 2007, p. 227-228). Gerber goes on to elaborate on the

ways that these obstacles can be addressed in a way that provides opportunities for policy learning.

Gerber (2007) elaborates on these foundational ideas of policy learning to delve into six propositions for a model of event-related policy change, which involve:

> "1) efforts at goal-oriented resolution of problems revealed by a focusing event will vary by the interests and motives of participants in a policy domain; 2) relatively few events occur as a focusing event; 3) group mobilization efforts are linked to specific events; 4) group mobilization is accompanied by a sort of discourse mobilization- an increase in discussion of key ideas; 5) policy change is more likely with an increased prominence of a key policy idea or set of ideas; and 6) a recognition that learning can decay over time" (Gerber, 2007, p 233).

These propositions are used as a means of "helping to discern why some events may invite learning and policy change, while others may not" (Gerber, 2007, p.233). Additionally, it provides a "means of contextualizing different types of learning after policy failures in order to understand whether event-based learning will occur" (Gerber, 2007, p.233).

In Vermont, disaster policy development primarily falls under the auspices of the office of Vermont Emergency Management, which exists under the Department of Public Safety for the State of Vermont. They develop a series of plans, including the Local Emergency Operations Plan (LEOP), which allows individual communities to coordinate disaster response; the Local Emergency Management Plan (LEMP), which mandates that municipalities must develop all-hazards plans to guide municipal emergency management operations; the Local Hazard Mitigation Plan, which are used to identify policies and actions that can be implemented over the long term to reduce risk and future losses, and which form the foundation for a community's long-term strategy to reduce disaster losses; the State Emergency Operations Plan (SEOP), which is the framework for

the coordination of Vermont capabilities to support local jurisdiction response with state-level resources in compliance with federal guidelines; and the State Hazard Mitigation Plan, which identifies the natural hazards that count potentially affect the state, and assesses risk and vulnerability to these hazards and identifies top priority mitigation actions at the state level (Vermont Emergency Management, 2018). According to the Vermont State Hazard Mitigation Plan, flooding is the most common recurring hazard event in Vermont.

In New York State, disaster recovery and the state multi-hazard mitigation plan falls under the Department of Homeland Security and Emergency Services. The New York plan is updated every three years, and documents New York's progress in identifying risks and mitigating natural hazards to avoid the loss of lives and injury, and reduce the damage to state-owned and –managed infrastructure. It also serves as a reference document and information source for local governments as they develop local hazard mitigation plans to reduce their own risk and assess the full suite of federal disaster funding (New York Department of Homeland Security and Emergency Services, 2018). Further information about the local hazard mitigation plans of Vermont and New York can be found in the section titled "Economic Impacts and Indicators."

Further considerations into the development and improvement of local, state, and federal disaster policy include amendments that allow for the adaptation to climate change, and, in the case of the Lake Champlain Richelieu River Basin, the opportunity to build transboundary cooperation in managing natural hazards.

3.5. Flood Mitigation in the LCRR Basin

In the United States, losses to individuals and families by flooding is mediated by the Federal Emergency Management Agency's (FEMA) National Flood Insurance Program, which "aims to reduce the impact of flooding on private and public structures...by providing affordable insurance to property owners, renters, and businesses and by encouraging communities to adopt and enforce floodplain management regulations" (Federal Emergency Management Agency, 2018). The National Flood Insurance Program was founded in 1968 following Hurricane Betsy's widespread destruction in New Orleans, Louisiana, and buoyed by the disinterest of private insurance agencies to provide flood coverage following the nearly $1.5 billion worth of damage (Michel-Karjan, 2010, p. 165). The US National Flood Insurance Program premiums are established by the federal government. A homeowner can purchase building and contents coverage "up to $250,000 and $100,000, respectively, but only if the community that he or she lives in participates in the program. This requires that a flood-risk map has been completed and that the appropriate public body has adopted adequate floodplain management regulations" (Michel-Kerjan and Kunreuther, 2011, p. 408). In Vermont, 22 out of 251 communities do not participate in the National Flood Insurance Program. Nine communities in New York State are not enrolled in the program (Federal Emergency Management Agency, 2018). In Vermont, the only community not participating in the NFIP is St. George.

In New York State, a similar process can be utilized in order to deal with the implications of flooding, but the system is fundamentally different across the border in Quebec. The Quebec government provides disaster financial assistance, which seeks to

"financially help the victims who have suffered damage or deployed temporary preventive measures during floods" (Quebec Government, 2018). Residents of affected municipalities can make claims for coverage through the government's website by filling out a series of forms outlining the financial damage done by floods. Opportunities to make claims become available following flooding events, and claims can only be made if the flood in question is acknowledged by the Quebec government (Quebec Government, 2018).

While the imperative for flood insurance programming is evident in the continued destruction of property, residential and otherwise, on and along floodplains, there is a particularly strong criticism of the flood insurance program in the United States. In their article titled, "Redesigning Flood Insurance," Michel-Kerjan and Kunreuther (2011) explore how, "around the globe in the past decade, disasters have led to unprecedented claims payments to insured victims, and government relief to aid the uninsured and the affected communities has risen to historic levels," a shift they attribute to, "increases in population, property values, and concentration of assets in hazard-prone areas" (Michel-Kerjan & Kunreuther, 2011, p. 408). Knowles and Kunreuther argue in their article, "Troubled Waters: The National Flood Insurance Program in Historical Perspective" that:

> "the problems we face in protecting the nation's people, property, and infrastructure from disaster are rarely due to a lack of expert knowledge. The challenge is…in crafting public policy that encourages individuals and communities in harm's way to undertake cost-effective loss-reduction measures, to encourage them to purchase insurance and take longer-term steps to slow or restrict development in dangerous coastal locations. This is even more critical today given the federal debt, projections of sea-level rise and the need for those currently residing in flood-prone areas to have safe homes in which to live" (Knowles and Kunreuther, 2014, p. 348-349).

An important element of the need for preventative measures to flooding, and not only insurance programming for post-disaster relief, is an acknowledgment of floodplain development policy in the United States and Canada. In Vermont, Kline and Cahoon explore the state's river corridor planning in their article, "Protecting River Corridors in Vermont," which primarily deals with restoring fluvial processes "through adoption of municipal fluvial hazard zoning and purchase of river corridor easements, or local channel and floodplain management rights" (Kline and Cahoon, 2010). Floodplain development impedes a floodplain's ability to play a key role in slowing water when rivers spill over riverbanks, as well as provide rich, productive land for agriculture (Mears and McKearnan, 2013, p. 197). Historically in Vermont, settlement patterns are characterized by "relatively compact urban form adjacent to highly dynamic river systems" (Smith et al., 2013, p. 82). Today, in Vermont, nearly 90% of municipalities regulate floodplain development in order to qualify for participation in the National Flood Insurance Program, although FEMA's minimum standards allow for construction in Special Flood Hazard Areas, which are commonly referred to as "hundred-year floodplains" (Mears and McKearnan, 2013, p.198).

A goal of this work is to ensure that those recommendations are socially acceptable and politically feasible, and the specific objectives to achieve those goals include:

- Assess the economic, social, and political responses to flooding in the transboundary LCRR basin;
- Investigate how the public across the LCRR basin, specifically in Vermont and New York, consider flood risk and what factors influence subsequent action;
- Test a model of public risk perception based on different socioeconomic and geographic factors;
- Assess how different groups within the LCRR basin prioritize flood mitigation decision criteria and consider what those outcomes mean for social acceptability;
- And compare and contrast public perception with perceptions of first responders responsible for flood management in the LCRR basin.

The results of these analyses work within the confines of a series of flood mitigation recommendations proposed by the greater IJC LCRR basin flood study, including the following four themes. Theme 1 is representative of structural mitigation measures, including dams and weirs. Theme 2 considers nature-based solutions, including upland water storage and wetland restoration. Theme 3 is emergency responses to flooding, including flood forecasting and early warning systems, and theme 4 considers policy changes as a tool for flood mitigation and management.

The integration of the information collected through this study will serve in the development of ultimate recommendations of a suite of flood mitigation measures that will, ideally, consider the wants and needs of the community it will impact. A better understanding of public perceptions offers valuable insights into what is important to community members, and what is not. It also displays where gaps in capacity are, and can point this study towards options that increase individual and community resilience through a greater and more targeted spread of information.

CHAPTER 4: FIRST ARTICLE: PUBLIC PERCEPTIONS OF FLOOD RISK IN THE LAKE CHAMPLAIN RICHELIEU RIVER BASIN

4.1. Introduction

River and lake flooding represent one of the most costly and impactful natural disasters, and requires integrated adaptation and mitigation efforts that are inclusive of the communities that span the systems encompassed within watersheds (Dottori et al., 2018). In the spring of 2011, The Lake Champlain Richelieu River (LCRR) basin, which includes communities in Vermont and New York in the United States, and Quebec in Canada, experienced the most severe flooding in its recorded history. This flooding event was the result of rapidly melting snowpack and heavy rainfall, and pushed Lake Champlain far beyond previously historical maximum flood levels. The Richelieu River, downstream and to the North, rose above flood stage for more than two months. This flood caused widespread damage to homes, agriculture, business, and infrastructure across the LCRR basin. Damages were estimated to be roughly $90 million, and thousands of residents were evacuated from their homes.

The spring 2011 floods were a catalyzing event that prompted the United States and Canadian governments to collaborate with local, state, and provincial governments to identify flood mitigation, forecasting, and preparedness. A component of this work is the consideration of the social acceptability and political feasibility of flood mitigation measures, which requires an understanding of public and decision-maker perceptions of flooding as an issue in their region, and their support for or opposition to various mitigation measures. Determining how individuals perceive flood risk, as well as think about and respond to flood risk, is important for policy-making, particularly with respect to "providing a basis of understanding and anticipating public responses to hazards and

improving the communication of risk information among lay people, technical experts, and decision-makers" (Slovic, 1987, p. 280).

For decades, experts in natural hazard planning have studied how flood losses can be mitigated, and have often utilized the developed understanding of risk perception as a tool for managing flood risk. Risk can be defined in this context as the likelihood and value of some possible future event, and is contingent upon the associated uncertainty that accompanies risk. A common phenomenon of uncertainty is that it leads people to depend on others to provide information (Eiser et al., 2012).

Risk perception is challenging to define because of the many factors that have been found to influence it. When evaluating hazards with a component of risk, people tend to rely on intuitive risk judgments, or risk perceptions (Botzen et al., 2009). Some research evaluates risk perception through a cultural lens, where perceived risk reflects the social context individuals find themselves in. Other studies utilize the axiomatic measurement paradigm, which focuses on the way people subjectively transform objective risk information, and interpret that information through the potential impact it could have on their lives (Slovic & Weber, 2002). Alternately, the psychometric paradigm considers perceived risk as a function of properties of hazards (Sjoberg, 2000). The nature of the psychometric paradigm is such that it attempts to quantify individuals' risk perceptions and attitudes through survey questionnaires, particularly through questions asked on rating scales about characteristics of risks, personal ability to cope, feelings, and attitudes.

Through a sociological lens, the value of risk perception:

> "challenges the essentially static, closed-system approaches that analysts employ in formulating risk estimates. Risk analysis assumes that data from past accidents and disasters can be used to project future risks. This runs counter to what sociologists have long known about risks and hazards, which is that human

> activity and social change continually modify societal, community, and individual vulnerability levels" (Tierney, 1999, p.228).

Quantifying risk perception allows for comparisons among specific groups in society (Kellens et al., 2013). For example, the differences in risk perception amongst respondents who have and have not experienced a flood can inform how they engage with flood risk, and the steps that they take to fortify their homes and belongings. This information can also be utilized by decision makers to consider how flood mitigation measures can be successfully administered in their communities.

Research into flood risk perception, and natural hazard risk in general, is often measured through surveys. Brilly and Polic (2005) carried out a flood risk perception survey, with a focus on a community with a high flood risk in Slovenia. They highlight "factors influencing amplification of perceived risk" (Brilly & Polic, 2005, p.346), which include personal characteristics (education, gender, age, etc.), situational factors (event out of personal control, inadequate resources, lack of confidence in authorities, recent dangerous events, etc.), and risk characteristics (immediate threat, direct health consequences, fear arousing danger, mortal cases, etc.). Key findings from their study indicated that surveys on flooding reveal the importance of early warnings in mediating the impacts of floods, in addition to the significance of keeping the public well informed. Their surveys also noted that governmental support for flood defense measures in the community were of great importance (Brilly & Polic, 2005, p. 354).

In the United States, the Federal Emergency Management Agency (FEMA) conducted a nationwide survey of flood risk awareness in United States households in 2012. The research objectives of this survey included gauging awareness of flood risk, knowledge of specific ways to mitigate flood risk, perception of barriers to mitigation

activities, and understanding of steps taken to reduce risks. Respondents were asked if they believed their community and home were at risk of flooding, what hazard mitigation actions were taken, reasoning behind why they did or did not act, and the methods that individuals use as sources of information (Federal Emergency Management Agency, 2013). The information collected from this survey was used by FEMA to increase general understanding of flood risk perceptions, inform community engagement, and evaluate the ways that relevant programs identify, mitigate, and communicate flood risk (Federal Emergency Management Agency, 2013).

Studying the way that residents of the Lake Champlain Richelieu River (LCRR) basin perceive the risk of flooding has the potential to inform components of the region's integrated flood mitigation response, including how and what to communicate to the public, where gaps in preparedness and understanding of protocol may be, and how the most vulnerable residents of the LCRR consider flood risk. This article explores the results of a household risk perception survey that uses hazard mitigation frameworks to examine flood risk perception in context, and considers how the public engages with flood risk, subsequent disaster communication, flood preparedness, and flood governance. Results from this survey provide insight into the socioeconomic and geographic determinants of risk perception, and highlight spaces where intervention is necessary and important with respect to flood mitigation in the LCRR basin communities. The survey that provides results for this study was developed through a systematic review of natural hazard risk perception literature, in addition to input from the multi-disciplinary team of researchers that seeks to develop effective flood mitigation strategies for the LCRR basin.

This systematic review of literature, complemented by studies on the impacts of flooding on social and economic life in the LCRR basin yielded three hypotheses that will be further explored through the analyses of this report.

H1: Household flood risk perception is impacted by socioeconomic characteristics that indicate greater social vulnerability, past flood experiences, and perceived community flood risk.

H2: The adoption of flood preparedness measures, including but not limited to relocating critical infrastructure and landscaping for stormwater management, is positively impacted by variables including income, home ownership, floodplain residency, and state of residence, in addition to flood experience.

H3: Opinions of flood mitigation policies are impacted by political ideology, home ownership, flood experience.

These hypotheses will be explored through an assessment of the household risk perception survey results. This study also explored whether the survey results aligned with impersonal impact theory. Impersonal impact theory posits that, "mass mediated messages affect people's perceptions of the prevalence of certain problems or risks within a society, but do not affect their perceptions of personal risks" (Park et al., 2001, p.282).

4.2. Methods

This household risk perception survey was developed through an exhaustive review of literature of risk perceptions of natural hazards, with a specific focus on flooding. Questions related to risk perception made up a significant portion of the survey, with respondents being asked to gauge their perception of personal and community flood risk, the likelihood of flooding at their home and in their community, and the subsequent impact of flooding. They were also asked questions that gauged their perception of flood risk relative to other hazards (natural and man-made), their opinions on different flood

mitigation measures, and what actions they had taken to prepare themselves and their households for floods. The full risk perception survey can be found in appendix A.

The household risk perception survey had the following objectives: to assess the socioeconomic and demographic determinants of flood risk perception, and to assess the socioeconomic and demographic determinants of preferences for the decision criteria used to prioritize flood mitigation measures.

Questions from this survey were divided into five categories: 1) natural hazard risk perception, 2) governance, 3) cost-benefit analysis, 4) flood mitigation measures, and 5) demographics. Natural hazard risk perception and governance questions were developed following extensive literature review and input from experts on risk perception, emergency management, and resilience. Cost-benefit analysis questions were provided by the economic team from this study, Ouranos. The flood mitigation measures section utilized a multi-criteria decision analysis (MCDA) technique to assess preferences and priorities through three exercises, which, when considered in tandem, provided weighted preferences from each respondent and the opportunity to develop weighted ranks of each criteria. Demographic questions were asked in order to glean the socioeconomic and demographic characteristics of participants.

There are an estimated 672,831 households in the LCRR basin, and 3,000 surveys were distributed to households within the basin in Vermont and New York. Increased sampling was carried out within counties in Vermont and New York that were considered "lakeside," although surveys were sent to households across the extent of the LCRR basin in order to consider all of the communities that would be impacted by potential flood mitigation measures. A probability-based, address-based sample of the Lake Champlain

Richelieu River Basin was used for survey dissemination, which followed the United States Postal Service's Delivery Sequence File for households in the United States. This sample was purchased from ASDE Survey Sampler, Inc. Each addressee was mailed a postcard in August 2019 with a brief description of the study, and a link to the online survey platform. This was followed by a physical survey and a pre-stamped envelope for easy return two months after the initial mailing date, in October 2019.

In order to geographically code responses and consider perceptions of risk and flood mitigation preferences with respect to location, each respondent was assigned a number that corresponds to their survey response.

The response rate for the United States iteration of this survey was a just over 5%, with 136 respondents completing a survey administered to 3,000 households. It is also not uncommon for studies of this nature to make inferences about public perceptions of natural hazard risk with this degree of response (Feldman et al., 2016; Kellens et al., 2012; Lindell et al., 2009; Lindell & Perry, 2000).

Many variables were coded as dummy variables in order to best assess the differences between two established groups. The following variables were coded as dummy variables: location (NY=1 and VT=0), flood experience (flood experience=1 and no flood experience=0), home ownership with (owners=1 and renters=0), gender (female=1 and nonfemale=0), education (less than a bachelors degree=1 and all others=0), and income (below the poverty line=1, all others=0). For the sake of analysis, risk perception and opinions of flood mitigation measures were also coded in a binary, with high/very high perception of flood risk coded as =1, and agree/strongly agree on flood mitigation measures coded as=1.

The following statistical analyses were performed to better understand the determinants of risk perception and support for various flood mitigation and preparedness measures. With respect to risk perception and opinions on flood mitigation measures, dependent variables were assessed via binary logistic regression and ordered logistic regression, respectively. The first model, which analyzed determinants of household flood risk perception, included independent variables such as demographic and geographic variables, and variables that indicated other elements of perceived risk and flood experience. The regression analysis that assessed support for flood mitigation measures used the same variables in a continuous format, in addition to using household flood risk perception as a dependent variable. The following analyses were carried out in SPSS v. 25 and Microsoft Excel.

4.3. Results

The United States iteration of the household risk perception survey had 136 individuals complete the survey. Respondents were randomly selected and assigned a code that aligned with their exact address, which allowed for specific geocoding. A geographic representation of respondents is provided below in figure 4.1., and the breakdown of respondents based on their county is provided in table 4.1. The sampling frame extended throughout the entirety of the LCRR basin, including upland communities, in order to ensure that potential flood mitigation measures were acceptable across the jurisdictions that were responsible for implementation of these measures, and not just those directly impacted by lake flooding.

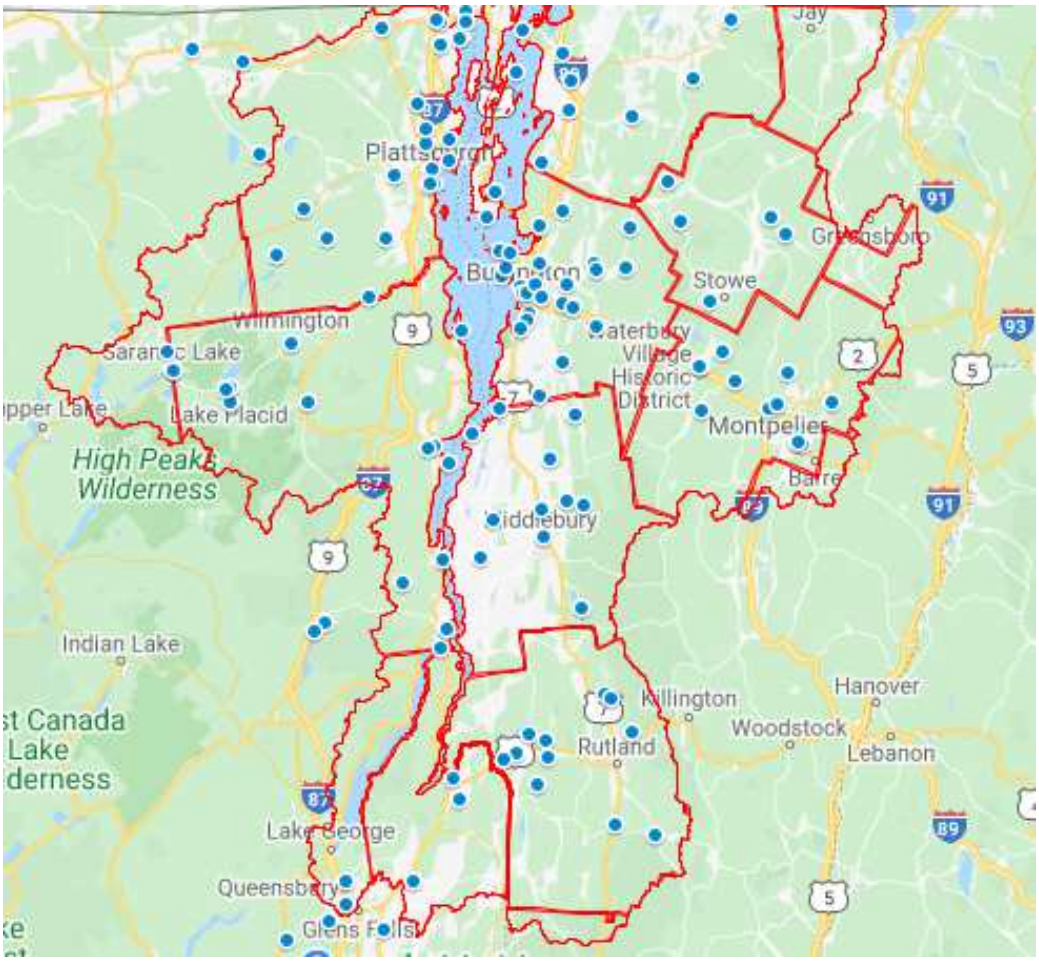

Figure 4.1. Map of respondents of the household risk perception survey in the United States section of the LCRR basin.

Table 4.1. Breakdown of counties represented in the household risk perception survey.

County	Respondents
State of New York	**58**
Clinton County, NY	27
Essex County, NY	16
Franklin County, NY	5
Warren County, NY	4
Washington County, NY	6
State of Vermont	**78**
Addison County, VT	11
Chittenden County, VT	27
Franklin County, VT	7
Grand Isle County, VT	3
Lamoille County, VT	5
Rutland County, VT	12
Washington County, VT	13

Note. N=136.

With respect to response rates across counties, the greatest representation is from the most populous counties in the LCRR basin, Clinton County, New York, and Chittenden County, Vermont. The descriptive statistics representing questions about the demographics of respondents is provided in table 4.2.

Table 4.2. Descriptive statistics of household risk perception survey.

Variable	Responses	Measure of Central Tendency (Standard Dev)
Residence type	Single family	76.7
	Multiple family	5.4
	Apartment	14.0
	Mobile Home	3.9
Home ownership	Own	82.9
	Rent	16.3
	I'd rather not say	0.7
Time in current home	>1 year	6.2
	1-5 years	24.0
	6-10 years	10.9
	11-15 years	14.7
	<15 years	44.2
Gender	Male	51.9
	Female	43.4
	Did not disclose	4.7
Age	Respondents age in years	52.46 (21.96)
Education level	9^{th}-12^{th} grade, no diploma	0.8
	High school grad/GED	10.1
	Some college, no degree	9.3
	Associate's degree	12.4
	Bachelor's degree	40.0
	Graduate degree	27.9
	Other	1.6
# people in household	1	20.9
	2	49.6
	3	13.2
	4	10.9
	5	2.3
	6+	3.2
# people under 18	0	77.5
	1	10.1
	2	10.2

	3+	2.4
# people over 65	0	58.9
	1	24.8
	2	16.3
Household income	>$10,000	0.8
	$10k-$14,999	3.9
	$15k-$24,999	1.6
	$25k-$34,999	9.3
	$35k-$49,999	10.9
	$50k-$74,999	17.8
	$75k-$99,999	18.6
	$100k-149,999	14.0
	$150k-$199,999	5.4
	<$200,000	0.0
	I'd rather not say	7.0
Political Ideology	Consistently conservative	3.9
	Mostly conservative	16.3
	Moderate	24.8
	Mostly liberal	16.3
	Consistently liberal	20.2
	I'd rather not say	12.4
	Other	6.2

Note. N=136.

A breakdown of the descriptive statistics from this survey, compared with census data, are provided in table 4.3., below. Some of the census numbers are the averages across the seven Vermont and five New York counties encompassed within the LCRR basin, including the percentage of people over the age of 65, education, and income. The gender, people per household, and home ownership numbers are reflective of Vermont and New York at the state level.

Table 4.3. Comparison of survey demographics with selected greater LCRR census data.

Variable	Survey	Vermont Census	New York Census
Age (% over 65 years)	41.1%	16.1%	18.1%
Gender (Female)	43.4%	51.1%	51.4%
Home ownership	82.9%	63.0%	53.9%
People per household	2.34	2.33	2.60
Education (High school graduate or higher)	89.9%	92.3%	88.5%
Education (Bachelor's degree or higher)	67.9%	62.5%	53.5%
Median household income	Between $50,000 and $74,999	$69,896	$65,323

Although there is consistency between the population and the respondent sample with respect to people per household, education levels, and household income, there is greater representation within the survey of respondents over the age of 65, male respondents, and homeowners. Overall, the survey results are representative of the counties and state where sampling took place.

There were several questions within the survey that assessed how respondents considered flood risk, including with respect to their households and communities, what the estimated likelihood of additional flooding was, and what the expected damage of a flood would be to their household. For this entire section of the survey, N=135.

Respondents were asked to consider the likelihood that flooding would occur at their current household in the next ten years. Responses were considered within the context of whether respondents had experienced flooding in the past. Respondents with flood experience indicated a higher likelihood of a future flooding event (51.7%) than those with no flood experience. Additionally, respondents with no flood experience

indicated that they expected the chance of a flood to be low or non-existent (93.4%). These results are visualized in table 4.4., below. A further exploration of the variables that shaped perceptions of flood risk are explored later in this section.

Table 4.4. Response to question: what do you estimate is the likelihood that you will experience a flood at your current home in the next ten years?

	Flood Experience	No Flood Experience
Very high	17.2	0.0
High	34.5	0.0
Neither high nor low	17.2	6.6
Low	10.3	24.5
Very low	3.4	47.2
There is no chance of a flood	17.2	21.7

A further exploration of the variables that shaped perceptions of flood risk are explored later in this section.

The responses to the questions that addressed fundamental perceptions of flood risk are presented below, in figures 4.2. and 4.3. Generally, respondents noted that they believed their communities were at risk of flooding (57%), but also noted that they did not believe that their households were at risk of flooding (66%).

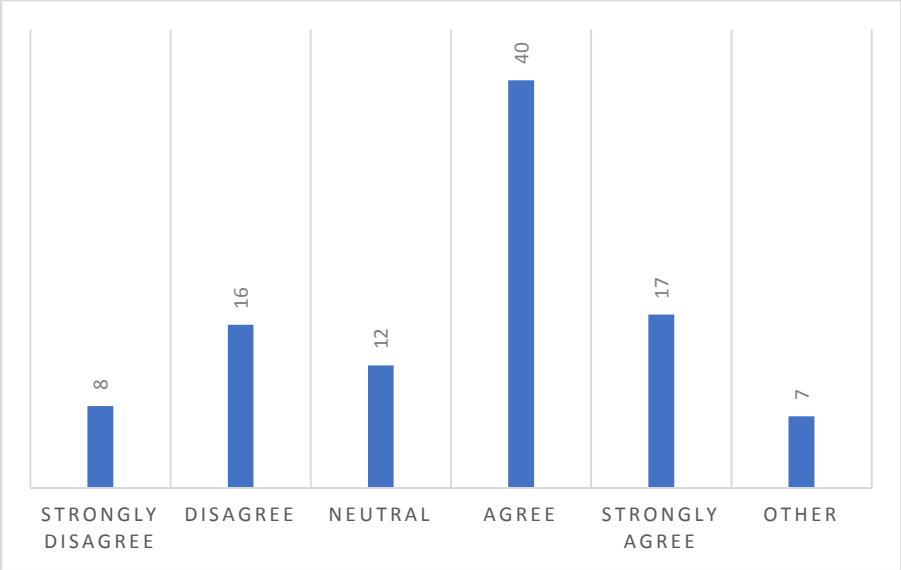

Figure 4.2. Percentage breakdown of responses to statement: I consider my community to be at risk of flooding.

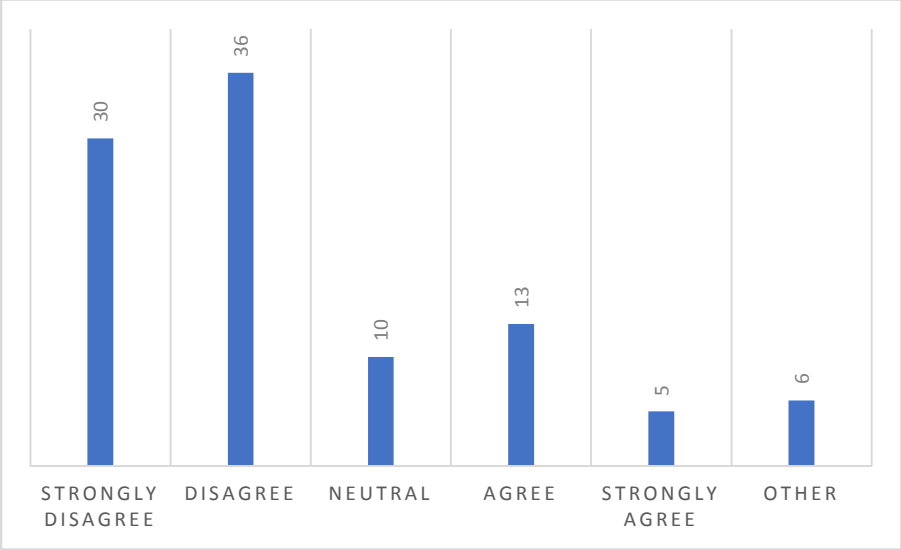

Figure 4.3. Percentage breakdown of response to statement: I consider my household to be at risk of flooding.

Respondents were also asked to consider how their flood risk stacked up against their neighbors. Most respondents indicated that they had lower than average flood risk (38.5%) or no flood risk (28.9 %). These results are visualized in table 4.5. Further insight into this perception is gained in later analyses.

Table 4.5. Comparative flood risk: How would you rate your flood risk compared to your neighbors?

Response	Percent
I have lower than average flood risk	38.5
I have no risk of flooding	28.9
I have an average flood risk	19.3
I have higher than average flood risk	7.4
I don't know my risk of flooding	5.9

Respondents were asked about the probability of experiencing a flood at their household; 64.4% of respondents indicated that they expected a flood would be impossible or nearly impossible. These results are visualized in table 4.6., below. Respondents were also asked to consider what the anticipated financial damage of a flood would be on their household. Responses were clustered either towards $0 of damage, or between $1,000-$100,000 worth of damage. These results are visualized in figure 4.6., below.

Table 4.6. Relative flood risk: How high do you estimate the probability that you experience a flood that damages property?

Rank	Percent
1	29.6
2	34.8
3	11.9
4	7.4
5	9.6
6	3.0
7	0.0
8	3.0
9	0.0
10	0.7

Note. Ranking schematic is 1=impossible, 10=extremely likely.

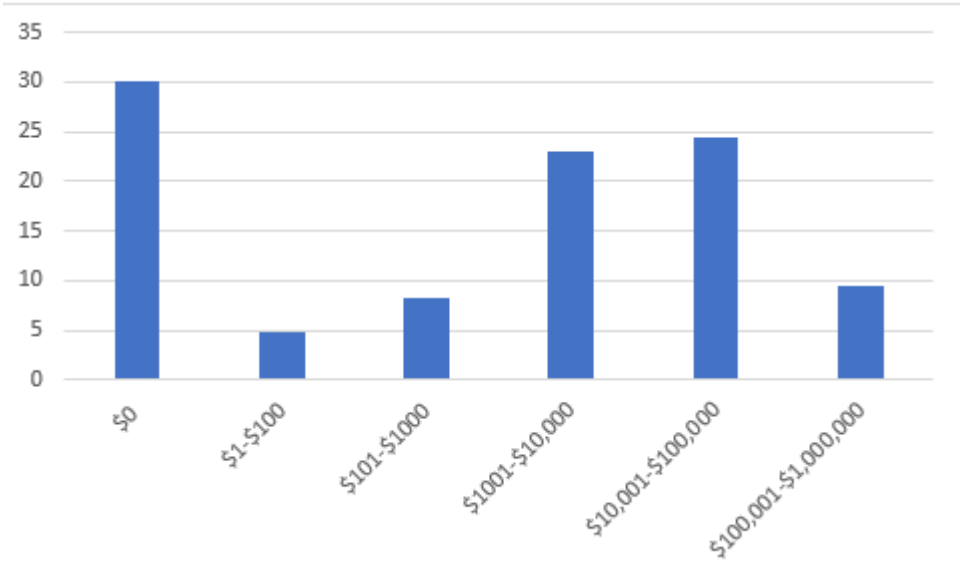

Figure 4.4. Response to question: how much financial damage do you expect that a single flood would cause to your home and belongings?

Table 4.7. presents the results of the binary logistic regression equation used to predict variables that contributed to household flood risk perception based on other predictors of risk perception, and based on a series of variables that indicated varied socioeconomic and geographic characteristics.

Table 4.7. Binary logistic regression results of household flood risk perception.

Variable	β	S.E.	Exp(β)	Wald	Sig.
Flood risk perception					
Flood experience	3.365	0.677	28.925	24.706	0.000*
Community flood risk perception	0.454	0.696	1.575	0.426	0.514
Socioeconomic characteristics					
Home ownership	0.062	0.891	1.064	0.005	0.944
Gender	-0.367	0.690	0.693	0.282	0.595
Education	-1.499	0.794	0.223	3.568	0.059
Age <65	-1.180	0.775	0.307	2.317	0.128
Political ideology	-2.080	1.347	0.125	2.386	0.122
Household income	-0.390	0.869	0.677	0.201	0.654
Location	0.369	0.649	1.446	0.322	0.570

P<0.05*

The binary logistic regression was performed to ascertain the effects of demographic, geographic, and experiential characteristics on the likelihood that respondents had a high perception of household flood risk. The logistic regression model was statistically significant: $X^2(3)=50.967$, $p<0.0005$. The model explained 53.1% (Nagelkerke R^2) of the variance in household flood risk perception and correctly classified 89.8% of cases. Respondents with flood experience were 24.7 times more likely to exhibit high household flood risk perception. Flood experience and education level added significantly to the model/prediction, but other variables did not add significantly to the model.

Another cluster of survey questions examined which measures respondents had taken to protect their household from flooding. Some of the flood preparedness options provided to respondents included structural changes to the home, including raising the

foundation of homes, building flood walls, raising homes onto stilts, and sealing basement windows. They were also asked about non-structural mitigation measures, including landscaping for storm water management, relocating critical systems within their homes, placing sandbags in advance of floods, and enrolling in the National Flood Insurance Program or private flood insurance. Most of the flood preparedness measures were not widely utilized amongst respondents. 30.1% of respondents did indicate that they had carried out landscaping for storm water management. 60.3% of respondents noted that they had not taken any steps to protect their home from flooding. A variety of factors could indicate why respondents did not take steps to fortify their households against the impact of flooding.

Table 4.8. Flood preparedness: Have you taken any of the following steps to protect your household from flooding?

Flood Preparedness Measure	Percent responded "yes"
I haven't taken any steps to protect my household from flooding	60.3
Landscaping for storm water management	30.1
Relocated critical systems (hearing, electric, hot water, etc.) from flood-prone levels	7.4
Sealed basement windows	5.1
Enrolled in the NFIP	2.9
Placed sand bags prior to or during a flooding event	2.9
Raised the foundation of your home	2.2
Built flood walls	1.5
Raised house onto stilts	1.5

To ascertain what variables impacted the adoption of certain flood preparedness measures, a series of cross tabulations were run. The adoption of each measure was considered through the lens of home ownership, flood experience, residence in a floodplain, location, and household income. Results of these crosstabulations are displayed below.

Table 4.9. Percentage of groups adopting flood preparedness measures.

	Land-scaping for Storm-water Manage-ment	Re-located Critical System-s	Sealed Base-ment Win-dows	Enrolled NFIP	Placed Sandbags	Raised Foundation of Home	Built Flood Walls	Raised Home onto Stilts
Home-owner	94.7	100.0	100.0	75.0	33.3	66.7	100.0	100.0
Flood-plain residence	4.9	20.0	0.0	75.0	0.0	33.3	0.0	0.0
Flood experi-ence	31.7	70.0	57.1	50.0	50.0	66.7	50.0	100.0
New York	34.1	30.0	71.4	75.0	25.0	0.0	0.0	100.0
Vermont	65.9	70.0	28.6	25.0	75.0	100.0	100.0	0.0
House-hold income below poverty line	2.5	0.0	0.0	0.0	25.0	33.3	0.0	0.0

As evidenced by table 4.9., the adoption of different household flood preparedness measures was impacted by a variety of variables. For instance, home ownership and flood experience played a substantial role in the adoption of flood preparedness measures that required structural adjustments to the home. Residence in a floodplain zone significantly impacted enrollment in the National Flood Insurance Program, while state residence appeared to play a role in the adoption of structural measures. Vermont respondents were more likely to participate in landscaping for stormwater management and the relocation of critical systems within their homes.

Another telling indicator was the percentage of respondents from these groups that did not adopt any measures to protect their homes from flooding. The breakdown of those results are provided in table 4.10., below.

Table 4.10. Percentage of respondents who did not participate in any flood preparedness measures.

Group	Percent
Homeowner	79.7
Floodplain residence	7.3
Flood experience	10.9
New York	51.2
Vermont	48.8
Household income below the poverty line	81.8

Homeowners represented a large group from within the survey sample (N=107). While homeowners represented the bulk of participation in flood preparedness measures, the overall percentage of homeowners (79.7%) did not take any steps to protect their homes from flooding. Alternately, most respondents who lived in a floodplain and experienced flooding did take measures to protect their homes. The small group representing households with incomes below the poverty line (N=11) did not generally take steps to protect their home, although there was some participation in placing sandbags and raising the foundation of their homes.

Finally, respondents were asked to provide their opinions regarding a series of statements that had to do with flood mitigation policies. Breakdowns of how survey participants responded to these statements are provided below in table 4.11.

Table 4.11. Responses to questions about flood mitigation policies.

Statement	Response	Percent	Mean	Standard Dev.
Government funds should be used to address flooding on private property	Strongly agree Agree Neutral Disagree Strongly disagree	11.5 23.8 26.9 22.3 15.4	2.94	1.24
Government funds should be used to reduce vulnerability before a flood	Strongly agree Agree Neutral Disagree Strongly disagree	26.9 49.2 13.8 4.6 5.4	3.88	1.03
Government funds should be used to help people repair damage after a flood	Strongly agree Agree Neutral Disagree Strongly disagree	18.2 40.2 19.7 15.9 0.61	3.48	1.14
Floodplain residents should be required to purchase insurance that would reimburse them for flood damage	Strongly agree Agree Neutral Disagree Strongly disagree	39.8 39.8 12.0 4.5 3.8	4.08	1.02
Flooding should be addressed by building projects that keep water away from development	Strongly agree Agree Neutral Disagree Strongly disagree	29.3 32.7 13.6 6.1 6.1	3.83	1.17

There was generally widespread support for all flood mitigation policies based on the assessment of the entire survey. The relationships between dependent variables were further explored through a series of ordered logistic regression that explored the effects of socioeconomic, geographic, and experiential variables impacted responses to the flood mitigation policy statements. Table 4.12. provides insight into the independent variables that were significant from these models. Results show that political ideology, particularly liberal-leaning tendencies, indicate support for flood mitigation policies that require government input. Additionally, flood experience had a positive impact on support for government funds to help people repair damage after a flood, and support for building projects that keep water away from development.

Table 4.12. OLS regression results of flood mitigation policies.

Dependent variable	Independent variables of significance	β	Significance
Government funds should be used to address flooding on private property	Political ideology	0.126	0.091*
Government funds should be used to reduce vulnerability before a flood	Gender (Female) Political ideology	-0.331 0.125	0.100* 0.041**
Government funds should be used to help people repair damage after a flood	Flood experience Political ideology	0.521 0.133	0.069* 0.043**
Floodplain residents should be required to purchase insurance that would reimburse them for flood damage	Household risk perception	-0.208	0.023**

Flooding should be addressed by building projects that keep water away from development	Flood experience	0.569	0.063*
	People <18	-0.313	0.050**

P<0.10*
P<0.05**
P<0.01***

4.4. Discussion

Information regarding how the public perceives the risk of natural hazards in the LCRR basin provides important insight into how to develop flood management programming that is socially acceptable and fills the needs of communities. Risk perception plays an important role in how individuals and communities respond to risk, since "perceptions of risk and risk related behaviors may amplify the social, political, and economic impact of disasters well beyond their direct consequences (Birkholz et al., 2014, p. 13; Burns & Slovic, 2012, p.579). The results of this study provide a look into the way that constituents from different backgrounds across the LCRR basin engage with various components of flood risk and flood mitigation in the LCRR basin. The following section will explore the implications that this information has for policies surrounding flood mitigation. Results will be further explored through the lens of the three hypotheses that guided this study.

The first hypothesis for this study indicated that there was an expected relationship between respondents who display social vulnerability due to low income and education and those who perceive household flood risk more acutely due to a limited capacity to mitigate flood risk through preparedness measures. Flood experience and education level contributed to increased perception of risk, but other factors did not have a significant effect on household flood risk perception, indicated a failure to reject the null hypothesis. This is counter to Brilly and Polic's (2005) study on flood risk

perception, which found that social factors have a substantial impact on risk perception, including lower education, gender, and age (Brilly & Polic, 2005, p.346). Additionally, in a review of flood risk perception research, social factors including residence characteristics and individual's physical location, socio-economic and demographic profiles, religious context, and political context were significant in impacting risk perception (Lechowska, 2018, p.1345).

The second hypothesis considered the effects that characteristics such as home ownership, flood experience, floodplain residency, state of residence, and household income had on adoption of flood preparedness measures. Due to the low incidence of flood preparedness measure adoption across the survey, cross tabulations were run to assess what percentage of respondents who enacted certain household flood preparedness measures belonged to certain groups. Results indicated that certain demographic and experiential factors, such as home ownership and flood experience, and floodplain residence, were significant in the adoption of flood preparedness measures.

Finally, the third hypothesis noted that flood mitigation strategies carried out by government are impacted by political ideology, homeownership, and flood experience. This was generally verified by the OLS regression, accepting the hypothesis. Additional factors, such as age, gender, education level, and state of residence were not significant variables in this model.

An additional consideration of this study was hypothesized that survey results would validate impersonal impact theory, which notes that, "mass mediated messages affect people's perceptions of the prevalence of certain problems or risks within a society, but do not affect their perceptions of personal risks" (Park et al., 2001, p.282). This

concept is interestingly displayed through the model which assessed what factors influence risk perception amongst respondents. In this study, household risk perception was directly related to flood experience and community risk perception, but not any socioeconomic factors.

Impersonal impact theory further notes that people tend to rely heavily on media coverage for a picture of society as a whole, but draw on personal experiences when considering their own lives (Park et al., 2001, p.282). This has implications for the dissemination of information about flooding. Those who have not directly experienced flooding and do not consider themselves to be at risk are less likely to take action. Interestingly, Tyler (1984) does note that the influence of interpersonal relationships has a strong capacity for shifting behavior towards risk mitigating and self-protective, displaying that social networks are more effective than media campaigns, particularly with respect to personal risk judgements (Park et al., 2001, p. 282).

This notion is further verified through the additional responses to questions regarding perceptions of flood risk. When asked about measures households have taken to protect themselves against flooding, the majority of households reported that no actions had been taken, even if they had a significant perception of flood risk. This is consistent with other studies on natural hazard risk perception, where data suggests that even if a hazard and its associated risk is well understood, the link between perceived risk and preparedness is mediated by additional factors (Paton et al., 2000, p.88; Burger & Palmer, 1992; Johnston et al., 1999; Lindell & Whitney, 2000). In certain instances, flood experience and flood risk perception impacted likelihood of adopting certain preparedness measures, particularly with respect to raising a house onto stilts, enrolling in

the NFIP, and relocating critical systems to higher floors in a home. It is important to note that while these variables were significant within the model, there was a low instance of participation in most flood preparedness measures by respondents, with over 60% responding that they had not taken any steps to protect their homes from flooding.

The final regression model run within the context of risk perception explored opinions on different flood mitigation measures. Experience with flooding was significant in the support for government funds being used to help people repair damage after a flood, and in government funds being used to facilitate building projects that keep water away from development. Political ideology was also significant, particularly with respect to mitigation measures that involved substantial governmental support, indicating that there was greater willingness amongst more liberal respondents to accept governmental intervention to reduce vulnerability to flooding.

Ultimately, the policy implications of this study point to the importance of understanding risk perception as a communication strategy, noting where discrepancies in risk perception may lie. For example, if forecasting distinguishes communities without a history of flooding as newly at risk due to climate change, it would be useful to assume a low perception of flood risk, and subsequently provide a high-engagement risk communication strategy. Additionally, creative measures of information sharing can effectively relay actual risks, such as through social networks and community resources rather than through top-down communication measures (Park et al., 2001).

This information provides useful insight into the development of integrated flood management, which includes reliance on publicly funded structural mitigation in addition to household and community-level actions. This requires long-term engagement based on

those at risk, policy-makers, and other stakeholders, and provides means of transmitting "correct" flood risk information, in addition to developing a negotiated shared responsibility for flood protection. To execute this kind of integrated flood management effectively requires an appreciation for how societies, including those not explicitly at risk, understand and value personal protection vs. public protection measures (Birkholz et al., 2014).

4.5. Conclusion

The design and implementation of flood mitigation measures at the local level, particularly in a transboundary context, requires appointed or elected authorities to manage the needs and interests of diverse stakeholders. Implementing public participation in flood mitigation decision-making processes can help local authorities develop mitigation strategies that fit into the local context and answer the social expectations of differing population subgroups as regards disaster mitigation (Affeltranger, 2001). The household risk perception survey administered on behalf on the International Joint Commission's LCRR flood study sought to do that, and has gathered information that provides context to decision-makers regarding the way their constituents perceive the risk of flooding, and the considerations that they have with respect to making decisions on flood management and mitigation.

There is great potential for further work in this arena, particularly with respect to what can be done with public perception information in political settings. Birkholz et al. (2014) provide a future research agenda for the field of natural hazard risk perception, noting that:

> "a greater engagement with constructivist perspectives might broaden and enrich this field of research by drawing attention to a wider range of flood risk

> perceptions (such as those of policy-makers, or those of tax payers who live outside flood affected areas) and their links with larger-scale protective measures (such as state-supported flood insurance schemes)" (Birkholz et al., 2014, p.18).

This constructivist perspective, described through Renn (1998) and Tierney's (1999) work, is very much explored through this research in part due to the diversity of responses received by this survey with respect to socio-economic and demographic characteristics, in addition to the opportunities this study has provided to compare public perception data with data provided by first responders and decision-makers.

A future research agenda prompted by the results of this study would move beyond simply exploring the diverse perspectives of the different actors involved in flood mitigation in the LCRR basin, and begin to consider how decision-makers digest the results of public perception research. A question to be posed could be: what are ultimately the most important variables when developing a new policy? Do decision-makers seek out the perceptions of those must vulnerable based on income, education, and age? Or are they more concerned with how those must vulnerable to flooding consider their risk. Additionally, the role that trust and information seeking relates to risk perception should be considered. These are all questions that could be answered through the strategic utilization of this research in further explorations.

4.6. References

Affeltranger, B. (2001). Public participation in the design of local strategies for flood mitigation and control (p. 48). Unesco.

Alfieri, L., Salamon, P., Pappenberger, F., Wetterhall, F., & Thielen, J. (2012). Operational early warning systems for water-related hazards in Europe. Environmental Science & Policy, 21, 35-49.

Becker, G., Aerts, J. C. J. H., & Huitema, D. (2014). Influence of flood risk perception and other factors on risk-reducing behaviour: a survey of municipalities along the R hine. Journal of Flood Risk Management, 7(1), 16-30.

Birkholz, S., Muro, M., Jeffrey, P., & Smith, H. M. (2014). Rethinking the relationship between flood risk perception and flood management. Science of the Total Environment, 478, 12-20.

Borga, M., Anagnostou, E. N., Blöschl, G., & Creutin, J. D. (2011). Flash flood forecasting, warning and risk management: the HYDRATE project. Environmental Science & Policy, 14(7), 834-844.

Botzen, W. J. W., Aerts, J. C. J. H., & Van Den Bergh, J. C. J. M. (2009). Dependence of flood risk perceptions on socioeconomic and objective risk factors. Water resources research, 45(10).

Brilly, M., & Polic, M. (2005). Public perception of flood risks, flood forecasting and mitigation.

Burger, J. M., & Palmer, M. L. (1992). Changes in and generalization of unrealistic optimism following experiences with stressful events: Reactions to the 1989 California earthquake. Personality and Social Psychology Bulletin, 18(1), 39-43.

Burns, W. J., & Slovic, P. (2012). Risk perception and behaviors: Anticipating and responding to crises. Risk Analysis.

Butler, C., & Pidgeon, N. (2011). From ‘flood defence’to ‘flood risk management’: exploring governance, responsibility, and blame. Environment and Planning C: Government and Policy, 29(3), 533-547.

Cools, J., Innocenti, D., & O’Brien, S. (2016). Lessons from flood early warning systems. Environmental science & policy, 58, 117-122.

Demeritt, D., Nobert, S., Cloke, H. L., & Pappenberger, F. (2013). The European Flood Alert System and the communication, perception, and use of ensemble predictions for operational flood risk management. Hydrological Processes, 27(1), 147-157.

Dottori, F., Szewczyk, W., Ciscar, J. C., Zhao, F., Alfieri, L., Hirabayashi, Y., ... & Feyen, L. (2018). Increased human and economic losses from river flooding with anthropogenic warming. Nature Climate Change, 8(9), 781-786.

Eiser, J. R., Bostrom, A., Burton, I., Johnston, D. M., McClure, J., Paton, D., ... & White, M. P. (2012). Risk interpretation and action: A conceptual framework for responses to natural hazards. International Journal of Disaster Risk Reduction, 1, 5-16.

Feldman, D., Contreras, S., Karlin, B., Basolo, V., Matthew, R., Sanders, B., ... & Serrano, K. (2016). Communicating flood risk: Looking back and forward at traditional and social media outlets. International Journal of Disaster Risk Reduction, 15, 43-51.

Federal Emergency Management Agency. (2013). FEMA's Risk Mapping, Assessment, And Planning.

Hartmann, T., & Driessen, P. (2017). The flood risk management plan: towards spatial water governance. Journal of Flood Risk Management, 10(2), 145-154.

Johnston, D. M., Lai, M. S. B. C. D., Houghton, B. F., & Paton, D. (1999). Volcanic hazard perceptions: comparative shifts in knowledge and risk. Disaster Prevention and Management: An International Journal.

Kellens, W., Terpstra, T., & De Maeyer, P. (2013). Perception and communication of flood risks: a systematic review of empirical research. Risk Analysis: An International Journal, 33(1), 24-49.

Kellens, W., Zaalberg, R., & De Maeyer, P. (2012). The informed society: An analysis of the public's information-seeking behavior regarding coastal flood risks. Risk Analysis: An International Journal, 32(8), 1369-1381.

Lechowska, E. (2018). What determines flood risk perception? A review of factors of flood risk perception and relations between its basic elements. Natural Hazards, 94(3), 1341-1366.

Lindell, M. K., Arlikatti, S., & Prater, C. S. (2009). Why people do what they do to protect against earthquake risk: Perceptions of hazard adjustment attributes. Risk Analysis: An International Journal, 29(8), 1072-1088.

Lindell, M. K., & Perry, R. W. (2000). Household adjustment to earthquake hazard: A review of research. Environment and behavior, 32(4), 461-501.

Lindell, M. K., & Whitney, D. J. (2000). Correlates of household seismic hazard adjustment adoption. Risk analysis, 20(1), 13-26.

Lodge, M. (2009). The public management of risk: The case for deliberating among worldviews. Review of Policy Research, 26(4), 395-408.

Pappenberger, F., Bartholmes, J., Thielen, J., Cloke, H. L., Buizza, R., & de Roo, A. (2008). New dimensions in early flood warning across the globe using grand-ensemble weather predictions. Geophysical Research Letters, 35(10).

Park, E., Scherer, C. W., & Glynn, C. J. (2001). Community involvement and risk perception at personal and societal levels. Health, Risk & Society, 3(3), 281-292.

Paton, D. (2008). Risk communication and natural hazard mitigation: how trust influences its effectiveness. International Journal of Global Environmental Issues, 8(1-2), 2-16.

Paton, D., Smith, L., & Johnston, D. M. (2000). Volcanic hazards: risk perception and preparedness. New Zealand Journal of Psychology, 29(2), 86.

Renn, O. (1998). The role of risk perception for risk management. Reliability Engineering & System Safety, 59(1), 49-62.

Rözer, V., Müller, M., Bubeck, P., Kienzler, S., Thieken, A., Pech, I., ... & Kreibich, H. (2016). Coping with pluvial floods by private households. Water, 8(7), 304.

Sjöberg, L. (2000). Factors in risk perception. Risk analysis, 20(1), 1-12.

Slovic, P. (1987). Perception of risk. Science, 236(4799), 280-285.

Slovic, P., & Weber, E. U. (2002). Perception of risk posed by extreme events. Regulation of Toxic Substances and Hazardous Waste (2nd edition)(Applegate, Gabba, Laitos, and Sachs, Editors), Foundation Press, Forthcoming.

Stephens, E., & Bates, P. (2015). Assessing the reliability of probabilistic flood inundation model predictions. Hydrological Processes, 29(19), 4264-4283.

Tierney, K. J. (1999, June). Toward a critical sociology of risk. In Sociological forum (Vol. 14, No. 2, pp. 215-242). Kluwer Academic Publishers-Plenum Publishers.

Tyler, T. R., & Cook, F. L. (1984). The mass media and judgments of risk: Distinguishing impact on personal and societal level judgments. Journal of Personality and Social Psychology, 47(4), 693.

Wachinger, G., Renn, O., Begg, C., & Kuhlicke, C. (2013). The risk perception paradox—implications for governance and communication of natural hazards. Risk analysis, 33(6), 1049-1065.

Yang, T. H., Yang, S. C., Ho, J. Y., Lin, G. F., Hwang, G. D., & Lee, C. S. (2015). Flash flood warnings using the ensemble precipitation forecasting technique: A case study on forecasting floods in Taiwan caused by typhoons. Journal of Hydrology, 520, 367-378

CHAPTER 5: SECOND ARTICLE: A MULTI-CRITERIA DECISION ANALYSIS OF PUBLIC PREFERENCES FOR FLOOD MITIGATION CRITERIA IN THE LAKE CHAMPLAIN RICHELIEU RIVER BASIN

5.1. Introduction

The Lake Champlain Richelieu River (LCRR) basin experienced unprecedented flooding in the spring of 2011, when heavy rainfall and snow melt caused the flood stage to be reached and maintain for 67 days, causing widespread impact to communities in Vermont, New York, and Quebec. In 2016, the International Joint Commission convened a study that sought to assess the technical, hydrological, environmental, social, and economic viability of different flood mitigation measures, with the goal of reducing the impact of flooding across the transboundary Lake Champlain Richelieu River (LCRR) basin. This manifested into the creation of four flood mitigation themes (figure 1.3) that would inform the development of a suite of policy recommendations to the governments of the United States and Canada. To best assess the social acceptability of these measures to the general public, a decision analysis was carried out on respondents of a household risk perception survey administered across the United States portion of the LCRR basin.

A popular tool for gauging the social and political acceptability of policies, particularly ones with multi-dimensionality and complexity due to the embeddedness within social-ecological systems, is multi-criteria decision analysis (MCDA). MCDA is a form of integrated sustainability evaluation, and utilizes a decision support approach that is suitable for addressing problems featuring high uncertainty, conflicting objectives, different forms of information, multiple interests and perspectives, and the accounting for complex and evolving biophysical and socio-economic systems (Wang et al., 2009; Qin et al., 2008; Ozelkan & Duckstein, 1996). MCDA has been used to deal with complexity in studies related to the development of community resilience and environmental stewardship, since “analytical decision frameworks offer a structured and deliberate

analysis of" the criteria used to select alternatives (Hermans et al., 2007, p. 543) and can enhance information dissemination, social learning, and negotiation among stakeholders (Evers et al., 2017). Some of the capacities of MCDA include showing the decision maker the "best way forward", identifying areas of greater and lesser opportunity, prioritizing options, clarifying the differences between options, helping stakeholders better understand a situation, and indicating the best allocation of resources (Calizaya et al., 2010; Dodgson et al., 2009). The value of MCDA, particularly in building resilience, is its capacity to provide a consistent methodology that integrates quantitative variables and qualitative judgments, and provides the opportunity for ranking and evaluating the effects of potential decisions and policy strategies (Carone, 2018, p.166). These studies provide "baseline information regarding social preferences" and "a structured context in which public preferences for ecosystem management can be evaluated quantitatively" (Smyth et al., 2009, p.622).

In order to assess the different mitigation measures across a consistent standard, nine decision criteria were collaboratively and iteratively developed by the multidisciplinary study board, and are provided below in table 5.1:

Table 5.1. Flood Mitigation Decision Criteria.

Criteria
Reduce the financial cost of flood damages
Reduce harm to economic activity due to flooding
Reduce the number of homes that are impacted by flooding
Reduce street closures due to flooding
Reduce potential injury, stress, or loss of life due to flooding
Reduce harm to vulnerable people due to flooding
Maintain healthy ecosystems, including clean water and thriving biodiversity
Prevent the spread of aquatic invasive species
Reduce harm to historical and culturally sensitive community sites due to flooding

This article explores the results of an MCDA carried out through a 2019 survey of households in the United States component of the LCRR basin. Respondents had the opportunity to provide ranks and scores on the decision criteria, which are then analyzed generally, and through a series of clusters meant to discern what demographic, geographic, and experiential factors influence preferences. Ultimately, the preference information gleaned from this study will influence stakeholders responsible for the development of flood mitigation measures that consider the social acceptability of that policy. Stakeholder engagement is defined as a social process working together to find a collective solution for a certain problem (Thaler & Levin-Keitel, 2016, p. 293). Diverse stakeholder engagement is essential to flood risk management (Thaler & Levin-Keitel, 2016, p.292; Renn, 2008)

5.2. Methods

The MCDA process typically follows four steps: (1) alternatives formulation and criteria selection, (2) criteria weighting, (3) evaluation, and (4) final treatment and aggregation. The weighting of criteria involves a process that includes input from respondents, and allows for the determination of relative importance of criteria. Alternatives are then ranked by MCDA method with criteria weights, and alternative ranking is ordered (Wang et al., 2009). In the case of this study, the development of alternative scenarios was not available at the time of this survey administration, so instead, survey respondents were asked to engage with the criteria individually.

The MCDA methodology utilized for this study is called the Technique for Ordered Preference by Similarity to Ideal Solution, or TOPSIS. TOPSIS was developed in 1981 in an effort to help select the best alternative with a finite amount of criteria

(Behzadian et al., 2012; Hwang and Yoon, 1981). TOPSIS is a simple ranking method that operates by ranking alternatives based on which alternatives have the "shortest distance from the positive ideal solution and farther distance from the negative-ideal solution" (Behzadian et al., 2012, p. 13052). Additionally, beneficial criteria are maximized and cost criteria are minimized (Behzadian et al., 2012). The process of carrying out TOPSIS is visualized in figure .1. below:

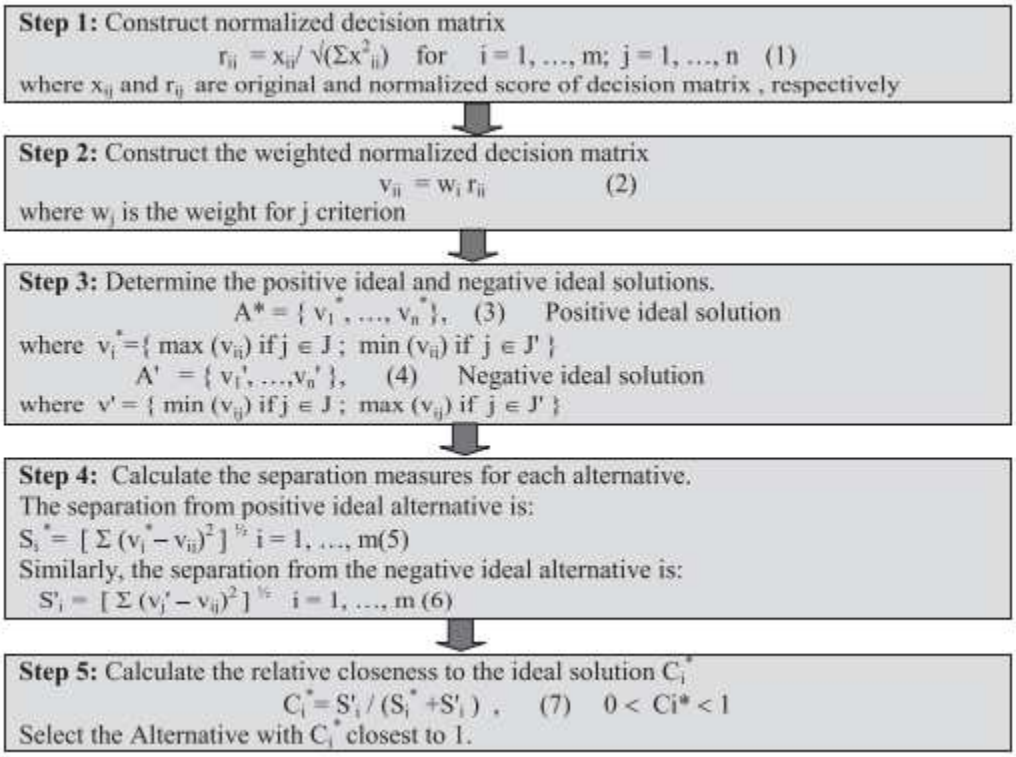

Figure 5.1. Stepwise procedure for performing TOPSIS methodology, retrieved from Behzadian et al., 2012, p.13052.

TOPSIS is often used in environmental assessments because it is a "reliable method for risk-avoidance because the designers may desire a decision that not only maximizes profit but also avoids risk" (Aghajani Mir et al., 2016, p. 112). In a review of applied TOPSIS in water resource management projects, Behzadian et al., (2012) explored the results of eight papers that utilized this methodology. In these instances,

researchers have used TOPSIS to help managers identify critical issues in water management and select the best compromised alternatives (Afshar et al., 2011), explore options for integrated water resource security (Dai et al., 2013), and evaluate real-time flood forecasting and flood simulation programs (Cheng et al., 2006). Support for this method within the relevant literature, and the capacity for TOPSIS to accommodate a modified MCDA process made it an ideal method for this study.

In this study, the alternatives were instead the nine decision criteria established by the LCRR basin flood study, and so the alternatives analyzed were actually the mean ranks and scores assigned to criteria by survey respondents. Since there were only two "criteria," rank and score, that were considered in the eyes of respondents, each criteria was assigned a weight of 0.5. The results of the TOPSIS analysis are provided in the results section.

The household risk perception survey was developed with the following objectives: to assess the socioeconomic and demographic determinants of flood risk perception, and to assess the socioeconomic and demographic determinants of preferences for the decision criteria used to prioritize flood mitigation measures.

Questions from this survey were divided into five categories: 1) natural hazard risk perception, 2) governance, 3) cost-benefit analysis, 4) flood mitigation measures, and 5) demographics. Natural hazard risk perception and governance questions were developed following extensive literature review and input from experts on risk perception, emergency management, and resilience. Cost-benefit analysis questions were provided by the economic team within the Social, Political, and Economic Technical Working Group, Ouranos. The flood mitigation measures section utilized techniques from MCDA to

assess preferences and priorities through three exercises, which, when considered in tandem, provided weighted preferences from each respondent and the opportunity to develop weighted ranks of each criteria. Demographic questions were asked in order to glean the socioeconomic and demographic characteristics of participants and their corresponding responses.

In the results section of this study, the outcomes of the TOPSIS analysis are compared with the results of a similar survey administered to first responders in the LCRR basin. That survey polled planners, emergency managers, and town administrators in communities in the LCRR basin in New York and Vermont, and exactly replicated the decision criteria preference questions administered in this survey.

A probability-based, address-based sample of the Lake Champlain Richelieu River basin was used for survey dissemination, which followed the United States Postal Service's Delivery Sequence File for households in the United States, and Telephone Directory listings for households in Canada. This sample was purchased from ASDE Survey Sampler, Inc. Each addressee was mailed a postcard with a brief description of the study, and a link to the online survey platform. This was followed by a physical survey and a pre-stamped envelope for easy return one month after the initial mailing date. Three versions of the survey were developed; one for American participants, and two for Canadian participants, which was translated to be culturally and politically relevant to Canadian respondents, and provided the opportunity for respondents to complete the survey in French or in English. The Canadian version of this survey will be administered in Fall of 2020.

There are an estimated 672,831 households in the Lake Champlain Richelieu River basin, and 3,000 surveys were distributed to households within the basin in Vermont and New York. Increased sampling was carried out within counties in Vermont and New York that were considered "lakeside." In order to geographically code responses and consider perceptions of risk and flood mitigation preferences with respect to location, each respondent was assigned a number that corresponds to their survey response.

The response rate for the United States iteration of this survey was roughly 5%, with 151 respondents completing a survey administered to 3,000 households. While this response rate is low, it is also not uncommon for studies of this nature to make inferences about public perceptions of natural hazard risk with this degree of response (Feldman et al., 2016; Kellens et al., 2012; Lindell et al., 2009; Lindell & Perry, 2000). This information indicates that low response rate within the context of natural hazard risk perception can still provide important insight into public perceptions, particularly when paired with demographic and geographic information. The results of this study, though limited by a small response rate, will still yield insight into the social acceptability of different flood mitigation measures across the LCRR basin.

To best analyze the results of questions that employed ranking exercises, a non-parametric Friedman test was used to assess the differences between ranks of governance responsibilities and decision criteria, respectively. These tests also provided a Kendall's W score, which is a non-parametric statistic that normalizes the results of the Friedman test, and assesses agreement among raters. The mean ranks and mean scores associated with the decision criteria exercises were then applied to the MCDA framework TOPSIS for the entire sample, as well as clusters related to flood experience, demographic characteristics,

and geographic location. A comparative analysis of preference results was also carried out between the public and respondents of the first responder survey.

5.3. Results

The United States version of this survey had 1 individuals complete the survey, with 135 usable responses. Respondents were randomly selected and assigned a code that aligned with their exact address, which allowed for specific geocoding. A geographic representation of respondents is provided below in figure 5.2.

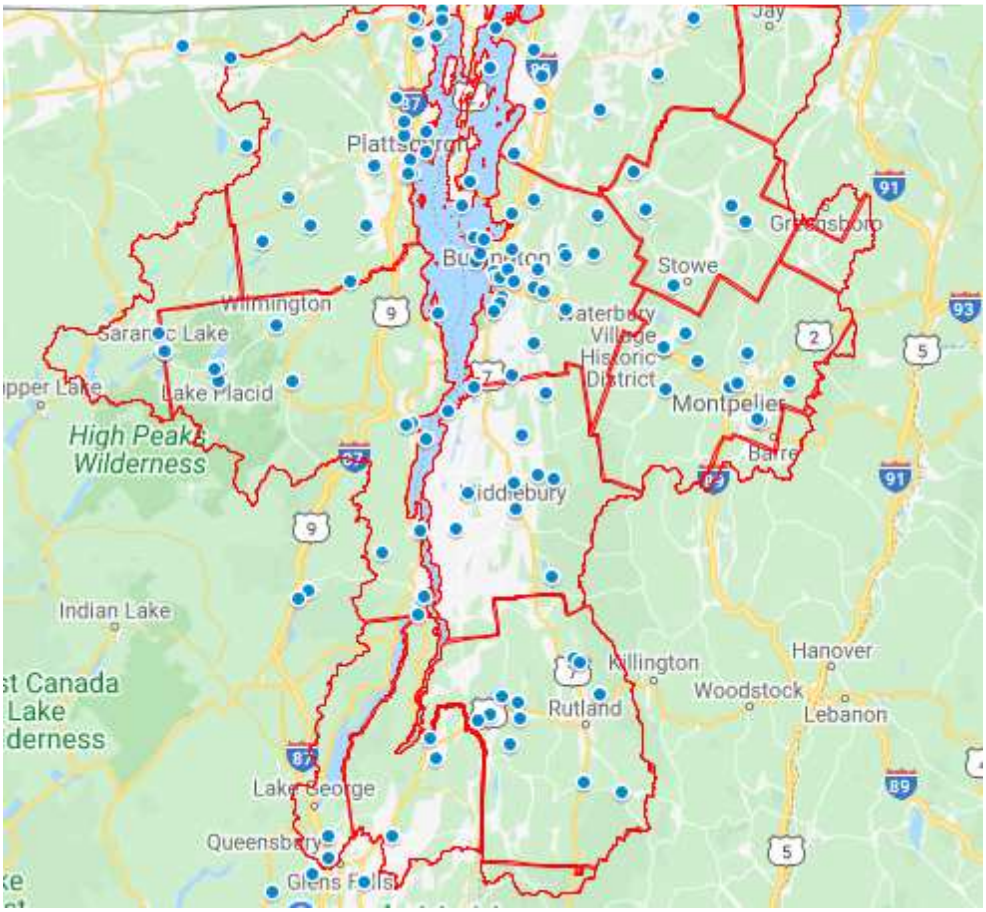

Figure 5.2. Map of respondents of the household risk perception survey in the United States section of the LCRR basin.

With respect to response rates across counties, the greatest representation is from the most populous counties in the LCRR basin, Clinton County, New York, and Chittenden County, Vermont. Relevant descriptive statistics representing are provided in table 5.2. For a full demographic profile of respondents, see tables 4.2 and 4.3.

Table 5.2. Descriptive statistics of household risk perception survey.

Variable	Responses	Measure of Central Tendency (Standard Dev)
Gender	Male	51.9
	Female	43.4
	Did not disclose	4.7
Age	Respondents age in years	52.46 (21.96)
Education level	9^{th}-12^{th} grade, no diploma	0.8
	High school grad/GED	10.1
	Some college, no degree	9.3
	Associate's degree	12.4
	Bachelor's degree	40.0
	Graduate degree	27.9
	Other	1.6

Note. N=136.

The nine decision criteria used in this survey, outlined in table 5.1., were developed as a product of the greater IJC study. The highest-ranked criterion was "reduce potential injury, stress, or loss of life due to flooding" (47.7%), followed by "maintain healthy ecosystems, including clear water and thriving biodiversity" (15.0%) and "reduce harm to vulnerable people" (14.6%). In contrast, the criteria that received the greatest number of last-place ranks was "reduce street closures" (28.5%), followed by "prevent the spread of aquatic invasive species" (22.3%) and "reduce harm to historical and culturally sensitive community sites due to flooding" (20.0%).

Following the ranking exercise, respondents were asked to engage with each decision criteria individually based on a Likert scale of importance, with 5 being the most

important and 1 being the least important. The mean score that each criterion received, along with standard deviation and range, are provided in table 5.3. The results were similar to the ranking exercise, with “reduce potential injury, stress, or loss of life due to flooding” (4.62) receiving the highest score, followed by “reduce harm to vulnerable people” (4.51) and “maintain healthy ecosystems, including clear water and thriving biodiversity” (4.48). It is important to note that during the ranking exercise, a lower score was favorable, while during the scoring exercise, a higher score was favorable. This was considered during the TOPSIS process by assigning ranks as a “cost” function, with a lower score being normalized as favorable, and scores being assigned as a “benefit” function, with a higher score being normalized as favorable.

Table 5.3. Descriptive statistics for scored decision criteria.

Decision Criteria	Mean	Standard Deviation	Range
Reduce potential injury, stress, or loss of life due to flooding	4.62	0.76	4
Reduce harm to vulnerable people due to flooding	4.51	0.90	4
Maintain healthy ecosystems, including clean water and thriving biodiversity	4.48	0.79	4
Reduce the number of homes that are impacted by flooding	4.09	0.92	4
Reduce the financial cost of flood damages	4.00	0.92	4
Prevent the spread of aquatic invasive species	3.99	1.04	4
Reduce harm to economic activity due to flooding	3.88	0.88	3
Reduce harm to historical and culturally sensitive community sites due to flooding	3.64	1.00	4
Reduce street closures due to flooding	3.50	1.01	4

Note. N=136.

To establish the means ranks from each respondent's exercise, a Friedman test was carried out first on the entire sample, and then over a series of clusters, including clusters by state and by flood experience. The Friedman test is a non-parametric statistical test that assesses variance by ranks. A Kendall's W normalized the information generated by the Friedman test, and is provided below as well. The mean ranks generated by the Friedman test were used in the TOPSIS analysis.

Table 5.4. Results of Friedman's test.

Criteria	Mean Rank
Reduce potential injury, stress, or loss of life due to flooding	4.39
Reduce street closures due to flooding	4.60
Reduce harm to vulnerable people due to flooding	4.70
Maintain healthy ecosystems, including clean water and thriving biodiversity	4.79
Prevent the spread of aquatic invasive species	5.18
Reduce the number of homes that are impacted by flooding	5.18
Reduce the financial cost of flood damages	5.20
Reduce harm to economic activity due to flooding	5.43
Reduce harm to historical and culturally sensitive community sites due to flooding	5.53

N=136
P<0.5
Chi-square: 23.331
Kendall's W: 0.021

Table 5.5. Results of Friedman's test by state and flood experience.

Criteria	NY	VT	Flood Experience	No Flood Experience
Reduce the financial cost of flood damages	5.17	5.22	5.24	5.19
Reduce harm to economic activity due to flooding	5.36	5.48	5.14	5.50
Reduce the number of homes that are impacted by flooding	5.20	5.17	5.24	5.17
Reduce street closures due to flooding	4.64	4.57	4.21	4.71
Reduce potential injury, stress, or loss of life due to flooding	4.32	4.44	4.66	4.32
Reduce harm to vulnerable people due to flooding	4.81	4.61	4.17	4.84
Maintain healthy ecosystems, including clean water and thriving biodiversity	4.85	4.75	4.69	4.82
Prevent the spread of aquatic invasive species	5.24	5.13	5.55	5.07

Reduce harm to historical and culturally sensitive community sites due to flooding	5.41	5.62	6.10	5.37
	N=59 Chi-square=8.655 Sig=.372 Kendall's W=0.018	N=77 Chi-square=15.397 Sig=0.052 Kendall's W=0.025	N=29 Chi-square=12.322 Sig=0.137 Kendall's W=0.053	N=107 Chi-square=16.164 Sig=0.040 Kendall's W=0.019

The results of the TOPSIS multi-criteria decision analysis provided insight not only into how the different populations sampled in this survey engage with the decision criteria relative to this study, but also how the combined effect of ranking and scoring these criteria alter the ultimate ranks by considering these components in tandem. TOPSIS operates by considering how far away each alternative criterion is from the "ideal solution," and interestingly, in some iterations of this analysis, the criteria "reduce potential injury, stress, or loss of life due to flooding" represented that ideal solution, with a performance score of 0. This means that that criteria was consistently rated the most important in both exercises. There was then significant distance between this ideal, first-ranked criteria, and the following criteria. In the case of the second- and third-ranked criteria, "reduce harm to vulnerable people" had a performance score of 0.17, and "maintain healthy ecosystems, including clean water and thriving biodiversity" had a performance score of 0.25.

"Reduce potential injury, stress, or loss of life due to flooding" was ranked first in every iteration of TOPSIS except for the cluster that represented respondents who had experienced flooding, who ranked "reduce harm to vulnerable people due to flooding"

first. Clustered results are provided in table 5.7. The criteria "reduce harm to historical and culturally sensitive community sites due to flooding" was consistently ranked last, and in certain instances, represented the ideal worst criteria with a performance score of 1, meaning it was consistently rated the least important in both exercises. This criterion was the ideal worst solution in the general sample, as well as the clusters representing Vermont and respondents who had experienced flooding in the past.

Each performance score represents the Euclidian distance that each criterion is from the ideal solution, which was calculated through a comparative analysis of ranks and scores. The ideal solution, or most highly regarded criteria, was "reduce potential injury, stress, or loss of life due to flooding." Considering the distance that each criterion is from this ideal solution provides important insight into how socially acceptable flood mitigation measures are with respect to how they score with these different criteria. The retroactive application of alternative scenarios to these performance scores would yield important insight into how to select the most acceptable flood mitigation measures based on the perceptions of certain groups within the LCRR basin.

Table 5.6. TOPSIS results of full survey.

Criteria	Normalized Ranks	Normalized Score	Weighted Ranks	Weighted Score	Performance Score	Ranks
Reduce the financial cost of flood damages	0.35	0.33	0.175	0.165	0.59	5
Reduce harm to economic activity due to flooding	0.36	0.32	0.18	0.16	0.69	8
Reduce the number of homes that are impacted by flooding	0.34	0.33	0.17	0.165	0.55	4
Reduce street closures due to flooding	0.31	0.28	0.155	0.14	0.63	7
Reduce potential injury, stress, or loss of life due to flooding	0.29	0.38	0.145	0.19	0	1
Reduce harm to vulnerable people due to flooding	0.31	0.37	0.155	0.185	0.17	2
Maintain healthy ecosystems, including	0.32	0.36	0.16	0.18	0.29	3

clean water and thriving biodiversity						
Prevent the spread of aquatic invasive species	0.34	0.32	0.17	0.16	0.61	6
Reduce harm to historical and culturally sensitive community sites due to flooding	0.37	0.30	0.185	0.15	0.85	9

Note. N=136.

Table 5.7. TOPSIS ranks by state and flood experience.

Criteria	Ranks	VT Ranks	NY Ranks	Flood Experience Ranks	No Flood Experience Ranks
Reduce the financial cost of flood damages	5	6	4	6	7
Reduce harm to economic activity due to flooding	8	8	6	5	8
Reduce the number of homes that are impacted by flooding	4	4	3	6	4
Reduce street closures due to flooding	7	5	5	3	6
Reduce potential injury, stress, or loss of life due to flooding	1	1	1	2	1
Reduce harm to vulnerable people due to flooding	2	2	2	1	2
Maintain healthy ecosystems, including clean water and thriving biodiversity	3	3	2	4	3
Prevent the spread of aquatic invasive species	6	7	7	7	5
Reduce harm to historical and culturally sensitive community sites due to flooding	9	9	8	8	9

Note. N=136.

Additionally, a series of demographic factors were explored to consider how certain characteristics impacted preferences. Those characteristics included gender, age, and educational level. Results from those clusters are displayed below, in table 5.8.

Table 5.8. TOPSIS ranks by demographics.

Criteria	Female Ranks	Male Ranks	Under 30 Ranks	30-60 Ranks	60+ Ranks	No BA Ranks	More than BA Ranks
Reduce the financial cost of flood damages	5	5	7	5	6	6	5
Reduce harm to economic activity due to flooding	7	7	9	6	5	7	6
Reduce the number of homes that are impacted by flooding	3	4	4	4	4	4	4
Reduce street closures due to flooding	9	9	8	8	9	9	9
Reduce potential injury, stress, or loss of life due to flooding	1	1	1	1	1	1	1
Reduce harm to vulnerable people due to flooding	2	2	3	2	2	2	2
Maintain healthy ecosystems, including clean water and thriving biodiversity	4	3	2	3	3	3	3
Prevent the spread of aquatic invasive species	6	6	5	7	7	5	7

Reduce harm to historical and culturally sensitive community sites due to flooding	8	8	6	9	8	8	8

The demographic cluster with the starkest difference in rankings was the group of respondents under the age of 30. This group, although small (N=13), had a greater propensity towards environmental conservation, and the protection of historically and culturally sensitive community sites. Otherwise, there was generally a consistent ranking in place, with some discrepancies towards the lower rankings. Overall, respondents prioritized human wellbeing and deprioritized infrastructure.

A study of first responder risk perception and decision criteria preference was carried out across the LCRR basin in February of 2020, when 44 first responders in Vermont, New York, and Quebec answered the same questions asked of the public in the first responder survey. First responders were classified as those in charge of managing emergencies related to natural hazards, primarily planners and emergency personnel. The way that these responses were similar of differed from the public they serve can provide a look into discrepancies or consistencies between key stakeholders in flood mitigation, and their constituents. The results of the TOPSIS exercise for first responders and the public is provided in table 5.9., below:

Table 5.9. TOPSIS ranks of public and first responders.

Criteria	Ranks	VT Ranks	NY Ranks	First Responder Ranks
Reduce the financial cost of flood damages	5	6	4	4
Reduce harm to economic activity due to flooding	8	8	6	6
Reduce the number of homes that are impacted by flooding	4	4	3	3
Reduce street closures due to flooding	7	5	5	5
Reduce potential injury, stress, or loss of life due to flooding	1	1	1	1
Reduce harm to vulnerable people due to flooding	2	2	2	2
Maintain healthy ecosystems, including clean water and thriving biodiversity	3	3	2	8
Prevent the spread of aquatic invasive species	6	7	7	9
Reduce harm to historical and culturally sensitive community sites due to flooding	9	9	8	7

5.4. Discussion

MCDA enables the elicitation of value trade-offs as a structed participatory mechanism for groups of stakeholders (Zia et al., 2011). In this case, trade-offs are assessed across the socio-economic and geographic boundaries of the LCRR basin. The opportunity to consider the preferences of the public and of first responders in this region provide insight into the preferences that respondents have towards the nine decision criteria developed for this study, and are able to display weighted valuation of these criteria and differences in preferences amongst different clusters of respondents, including in Vermont and New York, those with flood experience and those without, across the demographic spectrum, and of first responders as compared to the public they serve.

The TOPSIS results indicated consistency with the first-, second-, and third-ranked criteria, there was divergence on the lower ranked criteria, displaying stark differences in preferences across clusters. For instance, the bulk of the clusters had a third- or fourth-position ranking for the criteria "reduce the number of homes impacted by flooding," while those with flood experience ranked that criteria sixth. The New York cluster and the flood experience cluster also assigned higher ranks to the criteria "reduce harm to economic activity due to flooding," while the rest of the clusters had it ranked nearly last. There was a consistently low ranking for the criteria, "reduce harm to historical and culturally sensitive community sites due to flooding."

There was consistency in ranking amongst the clusters generated from the risk perception study. The results showed greater difference between the ranks from the first responders who completed the same exercise. While there was a strong preference for the criteria that sought to "maintain healthy ecosystems, including clean water and thriving biodiversity" amongst the public, first responders ranked that criteria nearly last. Additionally, there was higher regard for "prevent the spread of aquatic invasive species" amongst the public, and higher regard for the criteria that sought to protect homes and businesses by first responders. This is not unexpected, as the public completed the survey from their personal perspective, and first responders were asked to complete the survey through their professional capacity. Their priority is to protect the communities they serve, and not necessarily to act as conservationists.

The use of these results in the selection of alternative flood mitigation measures is not straightforward. Typically, the results of an MCDA analysis point to a clear decision pathway when applied to specific scenarios, although this case can "provide a structured

context in which public preferences can be evaluated quantitatively…and provide managers with information about how these tradeoffs can be made in a way that maximizes public support" (Smyth et al., 2009, p.622). While there are not clear policy alternatives available for the LCRR basin, there are four categories of recommendations that can allow for an exercise in visualizing how this data can be utilized in the future.

For instance, one can assign decision criteria that would be maximized by certain flood mitigation themes. This is visualized in table 5.10., below. This is an exercise, and as such, the assignments do not reflect the precise reality of the implications of the different flood mitigation themes.

Table 5.10. Alignment of flood mitigation themes with decision criteria.

Flood mitigation theme	Decision criteria
Theme 1: Structural mitigation measures that reduce water levels (i.e. dams, weirs)	• Reduce potential injury, stress, or loss of life due to flooding • Reduce harm to vulnerable people due to flooding • Reduce the number of homes impacted by flooding • Reduce street closures due to flooding
Theme 2: Upstream water management solutions that impede flows of water	• Maintain healthy ecosystems, including clean water and thriving biodiversity • Reduce harm to historical and culturally sensitive community sites due to flooding
Theme 3: Emergency response to flooding (i.e. flood forecasting, early warning systems)	• Reduce the financial cost of flood damages • Reduce harm to economic activity due to flooding
Theme 4: Floodplain management	• Prevent the spread of aquatic invasive species

In a fully implemented MCDA analysis, each criterion would have "levels" at which they could be rated for each mitigation alternative. For example, if structural mitigation measures would prevent the greatest amount of damage of human health and

well-being, it would be given a score of "5", while upstream water management may be given a score of "3." This would allow for a greater quantitative assessment of alternatives based on the given criteria. In this case, each cluster from the TOPSIS analysis indicated that they preferred flood mitigation measures that "reduced potential injury, stress, or loss of life due to flooding" and "reduced harm to vulnerable people due to flooding." With this insight alone, there is a strong argument for a flood mitigation measure that would halt flooding in its tracks, in line with theme 1. The challenge of assuming that there is correlation between preference and policy support requires the procurement of additional information, though. Interestingly, when respondents were asked to provide their opinion regarding the statement, "flooding should be addressed by building projects that keep water away from development," 62% of respondents indicated that they either agreed or strongly agreed.

The weighting schematic used in TOPSIS could then also incorporate further assessments from the scoring exercise that respondents undertook in the household risk perception survey, in order to place greater preference information onto the criteria prior to being assigned to mitigation measures.

Determining preferences based on how respondents ranked and scored decision criteria can assist in prioritizing flood management scenarios that are most socially acceptable to the public are essential when considering how to enact policies and programs that are politically feasible, particularly in a transboundary context. Through the assessment of the performance scores based on idealized best and idealized worst solutions, a strong preference for altruistic criteria was displayed. This consistency across Vermont and New York displays the significance of considering social wellbeing in the

development of flood mitigation measures beyond economic and environmental assessment. The quantification of stakeholder preferences also provides focus for research teams in their analysis of alternatives (Hermans et al., 2007).

The most significant output of this study, though, is that it provides space for learning across governance scales. In any collaborative decision-making process, education is vital, especially if the subject is complex as with transboundary flood mitigation. TOPSIS allowed for the quantification of public preferences, which in turn can contribute to the learning of key stakeholders who must select flood mitigation measures that will impact the public (Smyth et al., 2009). This research provides an opportunity for future discussions, including answering questions of how to mediate the discrepancy between public prioritization and first responder lack of prioritization of ecosystem health. Additionally, this research provides insight into the framing of flood mitigation measures for social acceptability. For example, if the public generally prioritizes human wellbeing and and population health, how can the effect of flood mitigatin measures on those criteria be highlighted?

5.5. Conclusion

This study provided insight into the preferences of the public and the stakeholders who manage flooding in the United States region of the LCRR basin, and considered a technique that provides a layer of complexity to the ways in which respondents engaged with the decision criteria developed by this study. This experiment considered the perspectives of diverse respondents across Vermont and New York, and was able to compare aggregated responses from various clusters, including state, flood experience, and the public with first responders.

The primary limitation to this study was the lack of alternatives available to point to clear decision preferences in a policy context, although preferences can prove useful to stakeholders who need to consider the perspectives of their constituents in these processes. Additionally, the cluster analyses were limited by the sample size.

There is exciting potential within the context of transboundary water management studies to use MCDA tools to manage the complexity of selecting the most socially acceptable and politically feasible policy options for a politically, economically, and culturally diverse social-ecological system. While it is effective to use survey instruments to administer TOPSIS and other MCDA exercises, they are also valuable within the decision-making spaces of public officials, where analyses can account for the weighted preferences of those involved. It would be fruitful for this study to re-administer this exercise as MCDA is traditionally carried out, with concrete alternatives provided to respondents, and criteria assigned values or scores based on the impact that the alternative would have upon it. While this was not possible during this specific iteration of this study, it paves the way for future research which can further explore the public viability of different flood mitigation measures.

5.6. References

Afshar, A., Mariño, M. A., Saadatpour, M., & Afshar, A. (2011). Fuzzy TOPSIS multi-criteria decision analysis applied to Karun reservoirs system. Water resources management, 25(2), 545-563.

Behzadian, M., Otaghsara, S. K., Yazdani, M., & Ignatius, J. (2012). A state-of-the-art survey of TOPSIS applications. Expert Systems with applications, 39(17), 13051-13069.

Calizaya, A., Meixner, O., Bengtsson, L., & Berndtsson, R. (2010). Multi-criteria decision analysis (MCDA) for integrated water resources management (IWRM) in the Lake Poopo Basin, Bolivia. Water resources management, 24(10), 2267-2289.

Carone, M. T., Marincioni, F., & Romagnoli, F. (2018). Use of multi-criteria decision analysis to define social resilience to disaster: the case of the EU LIFE PRIMES project. Energy Procedia, 147, 166-174.

Cheng, C. T., Zhao, M. Y., Chau, K. W., & Wu, X. Y. (2006). Using genetic algorithm and TOPSIS for Xinanjiang model calibration with a single procedure. Journal of Hydrology, 316(1-4), 129-140.

Dodgson J, Spackman M, Pearman A, Phillips L. (2009) Multi-criteria Analysis: A Manual. Department for Communities and Local Government. Accessed 24 April 2012, via: http://www.communities.gov.uk/documents/corporate/pdf/1132618.pdf.

Evers, M., Almoradie, A., & de Brito, M. M. (2018). Enhancing flood resilience through collaborative modelling and multi-criteria decision analysis (MCDA). In Urban Disaster Resilience and Security (pp. 221-236). Springer, Cham.

Feldman, D., Contreras, S., Karlin, B., Basolo, V., Matthew, R., Sanders, B., ... & Serrano, K. (2016). Communicating flood risk: Looking back and forward at traditional and social media outlets. International Journal of Disaster Risk Reduction, 15, 43-51.

Hermans, C., Erickson, J., Noordewier, T., Sheldon, A., & Kline, M. (2007). Collaborative environmental planning in river management: An application of multicriteria decision analysis in the White River Watershed in Vermont. Journal of Environmental Management, 84(4), 534-546.

Kellens, W., Zaalberg, R., & De Maeyer, P. (2012). The informed society: An analysis of the public's information-seeking behavior regarding coastal flood risks. Risk Analysis: An International Journal, 32(8), 1369-1381.

Lindell, M. K., Arlikatti, S., & Prater, C. S. (2009). Why people do what they do to protect against earthquake risk: Perceptions of hazard adjustment attributes. Risk Analysis: An International Journal, 29(8), 1072-1088.

Lindell, M. K., & Perry, R. W. (2000). Household adjustment to earthquake hazard: A review of research. Environment and behavior, 32(4), 461-501.

Mir, M. A., Ghazvinei, P. T., Sulaiman, N. M. N., Basri, N. E. A., Saheri, S., Mahmood, N. Z., ... & Aghamohammadi, N. (2016). Application of TOPSIS and VIKOR improved versions in a multi criteria decision analysis to develop an optimized municipal solid waste management model. Journal of environmental management, 166, 109-115.

Özelkan, E. C., & Duckstein, L. (1996). Analysing water resources alternatives and handling criteria by multi criterion decision techniques. Journal of environmental management, 48(1), 69-96.

Renn, O. (2008). *Risk governance: coping with uncertainty in a complex world*. Earthscan.

Smyth, R. L., Watzin, M. C., & Manning, R. E. (2009). Investigating public preferences for managing Lake Champlain using a choice experiment. Journal of Environmental Management, 90(1), 615-623.

Thaler, T., & Levin-Keitel, M. (2016). Multi-level stakeholder engagement in flood risk management—A question of roles and power: Lessons from England. *Environmental Science & Policy*, *55*, 292-301.

Wang, J. J., Jing, Y. Y., Zhang, C. F., & Zhao, J. H. (2009). Review on multi-criteria decision analysis aid in sustainable energy decision-making. Renewable and sustainable energy reviews, 13(9), 2263-2278.

Yoon, K. P., & Kim, W. K. (2017). The behavioral TOPSIS. Expert Systems with Applications, 89, 266-272.

Zia, A., Hirsch, P., Songorwa, A., Mutekanga, D. R., O'Connor, S., McShane, T., ... & Norton, B. (2011). Cross-scale value trade-offs in managing social-ecological systems: the politics of scale in Ruaha National Park, Tanzania. Ecology and Society, 16(4).

CHAPTER 6: CONCLUSIONS

Flooding is one of the most common and destructive natural hazards in the world. It does not adhere to political borders, nor does it discriminate against those in its path. Though flooding is a natural process, human development in river corridors and floodplains amplifies the impact that flooding has on communities who, be it deliberately or not, have placed themselves in danger. The management of flood hazards requires an integrated approach to address flooding as an issues within a social-ecological system, and must consider the social, economic, political, and environmental dimensions of various interventions.

The spring flooding event of 2011 had a profound impact on these components of life in the transboundary Lake Champlain Richelieu River (LCRR) basin, so much so that a study was convened to address the diverse impacts of flood, and develop a suite of recommendations aimed at addressing flooding's effect on human and ecological life in the region. A key component of this study was an examination of public and stakeholder perceptions about flooding in the LCRR basin, which manifested through a series of research programs aimed at exploring perceptions of flood risk, preferences regarding flood mitigation measures, and the governance of flood hazards. Ultimately, the goal of this work was to ensure that perceptions of the public and key stakeholders are considered during the development of flood mitigation measures, in order to ensure social acceptability and political feasibility.

The literature review, case study, and two articles presented in this thesis sought to provide information for policymakers to help in the decision-making process around flood mitigation measures in the LCRR basin, with an additional goal of building resilience to flooding in the LCRR basin. The literature review component of this thesis

considered the operationalization of flood management research, which set the tone of this body of work by considering the nexus of research and action. A primary component of this section considered the significance of integrating research on human behavior into studies that explore flood management, since the dynamic nature of flood risk management means that decision-making is perpetually informed not only by risk components, but also risk analysis and perception (Schanze, 2006, p.6).

The literature review then took a step back to consider the resilience frameworks that informed this study and included an examination of the social-ecological systems framework pioneered by Elinor Ostrom, and some of the frameworks that operationalized the ideas put forth by Ostrom. Particular attention was paid to how that manifestation occurred in the management of social-ecological systems in a transboundary context, and the use of the Disaster Resilience of Place (DROP) model. The literature review concluded with a look at the field of natural hazard risk perception, beginning with the conceptual models associated with risk perception, and concluding with case studies of risk perception studied geared at managing flood risk, and a look at how previous studies informed the development of the public perception survey developed for this thesis.

The third chapter of this thesis acted as a case study for the 2011 spring floods in the LCRR basin. This multidisciplinary chapter used economic data, news articles, and reports on the social and public health impacts of the floods to consider the diverse impacts this event had on the communities in Vermont, New York, and Quebec.

The first article of this thesis used the results of the risk perception component of the household survey administered in 2019 to consider the variables that impacted perceptions of flood risk, the adoption of flood preparedness measures, and support for

various flood mitigation measures. Findings indicated that experience with flooding was the primary driver of flood risk perception, while a variety of socio-demographic factors impacted respondents adoption of flood preparedness measures and support for flood mitigation policies.

The second article explored the results of a multi-criteria decision analysis (MCDA) that prompted respondents to assess flood mitigation decision criteria through ranking and Likert scale exercises. The MCDA method used in this study was called the Technique for Ordered Preference by Similarity to Ideal Solution (TOPSIS), and used the ranks and scores to weight and rank the decision criteria based on an "ideal best" criterion. TOPSIS was performed for the entire survey, and then performed on clustered groups. Clusters included those who had and had not experienced flooding, those based in Vermont and those based in New York, and first responders who completed the same iteration of MCDA that the public did. Further analyses applied TOPSIS to clusters based on gender, education level, income level, and home owners. The results of this analysis displayed that by and large, all respondents regardless of location or socio-economic status or experience prioritized human wellbeing in their criteria selection. The divergence occurred in the middle and lower rankings, where the public displayed preferences for environmental sustainability, while first responders indicated priorities in line with protecting economic health and infrastructure.

` The remainder of this chapter will explore the policy implications of this research, including the adoption of flood early warning systems, in addition to an exploration of what this research means for political feasibility and social acceptability. It will conclude with the limitations of this research, and prospects for future research.

6.1. Early Warning Systems

As far as policy implications of this work, a tangible tool for reducing flood risk is the development of an early warning system for the LCRR basin that considers the perceptions and knowledge gaps of residents is essential to building resilience to flooding. The term 'early warning' is used to denote the provision of information on an emerging dangerous circumstance where such information can enable action in advance, and subsequently reduce risks (Basher, 2006, p.2167). The development of Early Warning Systems (EWS) for natural haza rds has been cited as an important component of disaster risk reduction that has the capacity to save lives, prevent damage, and enhance the resilience of communities (Cools et al., 2016). With respect to flooding, EWS range in scale and scope from localized, community-based EWS to transnational EWS that uses state of the art technology to predict natural hazards and disseminate information to the proper channels (Demeritt et al., 2013; Alfieri et al., 2012). A well-built flood EWS "would provide decision makers and local response teams with sufficient information as to the source of flooding and local characteristics in addition to additional lead time to prepare preventive measures." (Yang et al., 2015, p. 367). Ultimately, the investment in improving EWS with respect to flooding contributes to the "development of a culture of risk prevention rather than relying on post-disaster response and recovery" (Alfieri et al., 2012, p.36) and enhance disaster resilience (Stephens et al., 2015a, 2015b). Early and effective flood warning is essential to initiate timely measures to reduce loss of life and economic damage (Pappenberger et al., 2008); indeed, with respect to pluvial flooding, or flooding directly linked to rainfall, "receiving a warning prior to a pluvial flood increases the chances to adequately protect lives and assets at risk,

by implementing emergency measures" (Rozer et al., 2016, p.304). In all types of management strategies, "forecasts, early warnings, and response play a key role as a primary step to mitigate the social and economic impacts of flash floods" (Borga et al., 2011, p.842).

At the Second International Conference on Early Warnings in 2003, it was determined that effective EWS are comprised of:

> "(1) Monitoring and warning service: Hazards are detected, monitored, forecasted, and hazard warnings are developed;
> (2) Risks knowledge: risks are analyzed and this information is incorporated in the warning messages;
> (3) Dissemination: Warnings are issued (by a designated authoritative source) and disseminated in a timely fashion to authorities and public at-risk; and
> (4) Response capacity: Community-based emergency plans are activated in response to warnings, to reduce potential impacts on lives and livelihoods" (Golnaraghi, 2012, p. 2).

In the years following this conference, research began to reveal that many nations around the world operate EWS for both natural and man-made hazards, although there is significant variation in the development and effectiveness of these systems, particularly in countries where there is high risk and fewer resources available (Golgaraghi, 2012). A highlight of best practices of EWS include the need for effective feedback and improvement mechanisms across all levels to provide systematic evaluation and ensure system improvement over time, and that training on risk awareness, hazard recognition, and related emergency response actions is integrated into various formal and informal educational programs linked to regularly conducted drills and tests across the system (Golgaraghi, 2012).

EWS can take many forms: that of top-down, state centric risk governance, people-centered, bottom up risk governance, and multilevel risk governance, the latter of

which engages local communities, regional authorities, and transboundary partnerships in collaborative agreements (Zia & Hammond, 2015, p. 197). Indeed, Zia & Hammond (2015) note that:

> "A business-as-usual, top-down implementation of the [Sendai Framework], operating through donor-driven programs and projects that do not strategically incorporate local communities through multi-level risk governance institutions, will not likely change the increasing trend of disasters" (Zia & Hammond, 2015, p. 197).

While this example is geared towards multi-hazard EWS in the developing world, the notion of holistic, cross-scale engagement for specified EWS, in this case for floods, rings true. One such component of the Sendai Framework includes for example, a call for:

> "media to take an active and inclusive role at the local, national, regional, and global levels in contributing to the raising of public awareness and understanding and disseminate accurate and non-sensitive disaster risk, hazard and disaster information, including on small-scale disasters, in a simple, transparent, easy-to-understand and accessible manner. In close cooperation with national authorities; adopt specific disaster risk reduction communications policies; support, as appropriate, early warning systems and life-saving protective measures; and stimulate a culture of prevention and strong community involvement in sustained public education campaigns and public consultations at all levels of society, in accordance with national practices" (United Nations- Headquarters" (UN), 2015, p.23)

The prevailing framework for EWS is a linear paradigm, emphasizing the hazard-focused, linear, top-down, expert driven systems with little or no engagement of end-users or their representatives. A challenge for addressing this issue is that while they are not holistically inclusive, people also tend not to have an interest in EWS until they are personally threatened (Basher, 2006). Some shortcomings of this paradigm include:

> "(1) the focus still tends to remain on the hazard, with less emphasis on the vulnerabilities, risk and response capacities
> (2) the different hazards are typically dealt with by separate independent technical institutions, with few synergies or mutual benefits being sought

> (3) the dominance of the expert can lead to difficulties in user appreciation of such things as the meaning of a warning, warning uncertainty, the nature of false alarms and the necessary responses to different types of warnings
> (4) the role of research and knowledge from outside the core area of expertise is often not acknowledged
> (5) there is little engagement or empowerment of those at risk in the design and operation of the warning system, and hence a tendency by users to lack any sense of ownership in the system and to mistrust the experts and authorities
> (6) there are few systematic mechanisms to improve the system through the incorporation of the knowledge, experience, and feedback from users and those at risk
> (7) weak public engagement and recognition tends to lead to weak political and budgetary support for the warning system" (Basher, 2006, p. 2172).

From these shortcomings, an integrated systems model was developed. The primary components of an EWS, including monitoring, system model, and prediction are complemented by the inclusion of actors typically withheld from such models. These actors include political-administrative supporting entities, as well as district and community actors, and the research community. The model is also complemented by the inclusion of multiple linkages and feedbacks, particularly between affected communities and political actors. This model could be further elaborated upon with the inclusion of particular circumstances to better express the collaborative roles of various institutions (Basher, 2006, p.2175

Ultimately, the purpose of concluding with a look at EWS is to consider how to integrate the above best practices into the development of an effective flood early warning system in the context of the Lake Champlain Richelieu River basin. Below are a series of considerations that must be undertaken within this study, and with input from emergency managers and first responders. Per these previous recommendations, stakeholders and decision makers should be asked about the following:

(1) Monitoring and warning service: How are flood hazards currently detected, monitored, and forecasted?
(2) Risks knowledge: To what extent are risks analyzed and how is this information incorporated in the warning messages?
(3) Dissemination: To what extent are warnings issued and disseminated in a timely fashion to authorities and the at-risk public, and what designated authority is responsible for circulating that information?
(4) Response capacity: To what extent do community-based emergency plans activated in response to warnings reduce potential impacts to lives and livelihoods?
(5) Accessibility: How can early warning systems be made more easily and readily accessible to all community members?
(6) Timeliness: How much lead time is required to effectively mitigate the impacts of a flood in your community?
(7) Integration: How can EWS be tied to response actions taken by people and organizations in advance of, during, and after a flooding event
(8) Uncertainty: How much information uncertainty can be tolerated?
(9) Vulnerable populations: Who are the vulnerable populations in the community? What is the best means of reaching vulnerable populations? What are the barriers to doing so? (Adapted from Zurich Floods Resilience Program, 2019; Golnaraghi, 2012, p.2; Basher, 2006).

The operationalization of flood management research, through the development of EWS and other strategies, requires an exploration of key concepts in the resilience of social-ecological systems, and how perceptions of risk can lend insight into the development of policies and programs meant to mitigate the impact of flooding.

6.2. Policy Implications

One of the primary policy implications of this research are the ways that public perception and preference information influence the political feasibility of flood mitigation measures, and the ways that that public knowledge influences the development of tools aimed at addressing those knowledge discrepancies to build resilience to flooding. Political feasibility is defined as analysis that leads to policies that can get implemented, and is a way of bridging the gap between the desirable and the possible (Meltsner, 1972). To reach politically feasible flood mitigation measures, there must be

place-specific knowledge (Lyles et al., 2013) that considers the costs and benefits, distribution of power, and an understanding of the institutional setting within which decision-making takes place (Skodvin, 2007) The information gathered in this study will be used in conversation with key stakeholders and decision makers, so as to provide a full picture of constituent perceptions and preferences. The subsequent analysis that took place through this study increases the likelihood of political feasibility, and subsequently, acceptability.

With respect to flood risk perception, the policy implications of this study point to the importance of understanding risk perception as a communication strategy, noting where discrepancies in risk perception may lie. For example, if forecasting distinguishes communities without a history of flooding as newly at risk due to climate change, it would be useful to assume a low perception of flood risk, and subsequently provide a high-engagement risk communication strategy. Additionally, creative measures of information sharing can effectively relay actual risks, such as through social networks and community resources rather than through top-down communication measures (Park et al., 2001).

This information provides useful insight into the development of integrated flood management, which includes reliance on publicly funded structural mitigation in addition to household and community-level actions. This requires long-term engagement based on those at risk, policy-makers, and other stakeholders, and provides means of transmitting "correct" flood risk information, in addition to developing a negotiated shared responsibility for flood protection. To execute this kind of integrated flood management effectively requires an appreciation for how societies, including those not explicitly at

risk, understand and value personal protection vs. public protection measures (Birkholz et al., 2014).

With respect to the decision criteria preferences, determining preferences based on how respondents ranked and scored decision criteria can assist in prioritizing flood management scenarios that are most socially acceptable to the public are essential when considering how to enact policies and programs that are politically feasible, particularly in a transboundary context. Through the assessment of the performance scores based on idealized best and idealized worst solutions, a strong preference for altruistic criteria was displayed. This consistency across Vermont and New York displays the significance of considering social wellbeing in the development of flood mitigation measures beyond economic and environmental assessment. The quantification of stakeholder preferences also provides focus for research teams in their analysis of alternatives (Hermans et al., 2007).

The most significant output of this study, though, is that it provides space for learning across governance scales. In any collaborative decision-making process, education is vital, especially if the subject is complex as with transboundary flood mitigation. TOPSIS allowed for the quantification of public preferences, which in turn can contribute to the learning of key stakeholders who must select flood mitigation measures that will impact the public (Smyth et al., 2009). This research provides an opportunity for future discussions, including answering questions of how to mediate the discrepancy between public prioritization and first responder lack of prioritization of ecosystem health. Additionally, this research provides insight into the framing of flood mitigation measures for social acceptability. For example, if the public generally

prioritizes human wellbeing and population health, how can the effect of flood mitigation measures on those criteria be highlighted?

6.3. Limitations of the Research

There are a number of fundamental limitations to this research that must be acknowledged. First, the response rate for the United States iteration of this survey was a little over 5%, with 151 respondents completing a survey administered to 3,000 households. It is not uncommon for studies of this nature to make inferences about public perceptions of natural hazard risk with this degree of response (Feldman et al., 2016; Kellens et al., 2012; Lindell et al., 2009; Lindell & Perry, 2000). The following section provides insight into the way similar studies have handled low response rates, and their justification for the validity of their data.

In 2009, Lindell et al., conducted a survey in Southern California regarding the adoption of hazard mitigation measures, specifically with respect to earthquakes. The total number of respondents across three communities was 553, which, according to the authors, was low. The authors indicated that "low response rates affect correlations only if the item variances were severely restricted by severe overrepresentation of respondents at one end of the response distribution" (Lindell et al., 2009, p. 1075).

A study carried out in 2012 in Belgium sought to establish the empirical relationship between information-seeking behavior and perceptions of risk. A survey was administered with a response rate of 6.3%. The authors noted that, "a low response rate does not constitute a significant obstacle to drawing statistical conclusions" (Kellens et al., 2012, p.1375; Lindell & Perry 2000).

Additionally, a survey conducted in 2014 in Newport Beach, California, assessed the current and preferred mechanisms through which individuals receive information on flood risk in their communities (Feldman et al., 2016). 2,448 households were sampled, and 164 households responded to their survey, producing a response rate of 6.7%. The implications of this study were that responses provided "useful insights about risk communication for flooding and suggest possible avenues for future research" (Feldman et al., 2016, p. 49) and that the findings from this survey would guide focus groups to establish the relevance of certain practices for flood management and mitigation (Feldman et al., 2016, p.49; Paton et al., 2001).

This information indicates that low response rate within the context of natural hazard risk perception can still provide important insight into public perceptions, particularly when paired with demographic and geographic information. The results of this study, though limited by a small response rate, will still yield insight into the social acceptability of different flood mitigation measures across the LCRR basin.

Additional limitations to research include the previously mentioned lack of decision alternatives, and the challenges of aligned this survey research with the developments and needs of the International Joint Commission LCRR basin study.

6.4. Future Research

There are a multitude of opportunities for further and future research in this arena. First, the opportunity to carry out a full MCDA with concrete policy alternatives would direct decision-makers towards feasible flood mitigation measures, although in this instance, public preferences are just as useful in the deliberative process. Additionally, further integration of this research with Canadian data provides a transboundary

examination of flood risk perception and flood mitigation preferences, which allows for complex considerations into managing varying perceptions across physical borders. Finally, there is great opportunity for this research to set the stage for further transboundary social science research through the auspices of the International Joint Commission, of which this study represents the pilot of a social, political, economic working group.

Additionally, there is space here to consider the frontiers of research than this work can contribute to, and continue to build upon. Within the realm of flood risk perception research, research on "the determinants and the effects of flood risk communication is in its early stages…and should address the relation between flood risk perception and flood risk communication more thoroughly" (Kellens et al., 2013, p.32). There is also research potential in examining how perceptions of risk influence vulnerability, capacity, and resilience (Birkholz et al., 2014, p.18).

Finally, there is an invigorated effort to continue to consider how to shift the framework of flood management, and natural hazard mitigation in general, towards a resilience perspective. Climate change, urbanization, and other mounting challenges require an approach to environmental management that fortifies community capacity to withstand disturbance and uncertainty, rather than "reactive behavior [which is] is insufficient for maintaining social-ecological resilience because…it is usually too late to avoid them" (Fazey et al., 2007, p. 376). The shift towards a resilience framework represents an orientation towards a systems perspective, and sees "adaptive capacity as a core feature of resilient social-ecological systems" (Nelson et al., 2007, p.395). Further

research into how to transcend problem solving and consider community capacity is essential as we move forward into an uncertain social, political, and economic future.

REFERENCES

Abbas, H. B., & Routray, J. K. (2014). Vulnerability to flood-induced public health risks in sudan. *Disaster Prevention and Management, 23*(4), 395-419. doi:10.1108/DPM-07-2013-0112

Affeltranger, B. (2001). Public participation in the design of local strategies for flood mitigation and control (p. 48). Unesco.

Afshar, A., Mariño, M. A., Saadatpour, M., & Afshar, A. (2011). Fuzzy TOPSIS multi-criteria decision analysis applied to Karun reservoirs system. Water resources management, 25(2), 545-563.

Alderman, K., Turner, L. R., & Tong, S. (2012). Floods and human health: A systematic review. *Environment International, 47*, 37-47. doi:10.1016/j.envint.2012.06.003

Alfieri, L., Salamon, P., Pappenberger, F., Wetterhall, F., & Thielen, J. (2012). Operational early warning systems for water-related hazards in Europe. Environmental Science & Policy, 21, 35-49.

Akamani, K., & Wilson, P. I. (2011). Toward the adaptive governance of transboundary water resources. *Conservation Letters*, *4*(6), 409-416.

Armitage, D., Marschke, M., & Plummer, R. (2008). Adaptive co-management and the paradox of learning. *Global environmental change*, *18*(1), 86-98.

Baan, P. J., & Klijn, F. (2004). Flood risk perception and implications for flood risk management in the Netherlands. *International journal of river basin management*, *2*(2), 113-122.

Bakker, M. H. N. (2009). Transboundary river floods and institutional capacity. *Journal of the American Water Resources Association*. doi:10.1111/j.1752-1688.2009.00325.x

Banks, L., Davenport, L. A., Hayes, M. H., McArthur, M. A., Toro, S. N., King, C. E., & Vazirani, H. M. (2016). Disaster impact on impoverished area of us: An inter-professional mixed method study. *Prehospital and Disaster Medicine, 31*(6), 583-592. doi:10.1017/S1049023X1600090X

Basher, R. (2006). Global early warning systems for natural hazards: systematic and people-centred. *Philosophical transactions of the royal society a: mathematical, physical and engineering sciences*, *364*(1845), 2167-2182.

Becker, G., Aerts, J. C. J. H., & Huitema, D. (2014). Influence of flood risk perception and other factors on risk-reducing behaviour: a survey of municipalities along the R hine. Journal of Flood Risk Management, 7(1), 16-30.

Behzadian, M., Otaghsara, S. K., Yazdani, M., & Ignatius, J. (2012). A state-of the-art survey of TOPSIS applications. Expert Systems with applications, 39(17), 13051-13069.

Bigger, J. E., Willingham, M. G., Krimgold, F., & Mili, L. (2009). Consequences of critical infrastructure interdependencies: lessons from the 2004 hurricane season in Florida. *International journal of critical infrastructures*, *5*(3), 199-219.

Birkholz, S., Muro, M., Jeffrey, P., & Smith, H. M. (2014). Rethinking the relationship between flood risk perception and flood management. Science of the Total Environment, 478, 12-20.

Bizikova, L., Roy, D., Swanson, D., Venema, H. D., & McCandless, M. (2013). *The water-energy-food security nexus: Towards a practical planning and decision-support framework for landscape investment and risk management*(pp. 16-20). Winnipeg: International Institute for Sustainable Development.

Bonaiuto, M., Alves, S., De Dominicis, S., & Petruccelli, I. (2016). Place attachment and natural hazard risk: Research review and agenda. *Journal of Environmental Psychology*, *48*, 33-53.

Borga, M., Stoffel, M., Marchi, L., Marra, F., & Jakob, M. (2014). Hydrogeomorphic response to extreme rainfall in headwater systems: flash floods and debris flows. *Journal of Hydrology*, *518*, 194-205.

Borga, M., Anagnostou, E. N., Blöschl, G., & Creutin, J. D. (2011). Flash flood forecasting, warning and risk management: the HYDRATE project. Environmental Science & Policy, 14(7), 834-844.

Botzen, W. J. W., Aerts, J. C. J. H., & Van Den Bergh, J. C. J. M. (2009). Dependence of flood risk perceptions on socioeconomic and objective risk factors. Water resources research, 45(10).

Brilly, M., & Polic, M. (2005). Public perception of flood risks, flood forecasting and mitigation.

Brondizio, E. S., Ostrom, E., & Young, O. R. (2009). Connectivity and the governance of multilevel social-ecological systems: the role of social capital. *Annual review of environment and resources*, *34*.

Bronstert, A. (2003). Floods and climate change: interactions and impacts. *Risk Analysis: An International Journal*, *23*(3), 545-557.

Burby, R. J. (2006). Hurricane Katrina and the paradoxes of government disaster policy: bringing about wise governmental decisions for hazardous areas. *The Annals of the American Academy of Political and Social Science*, *604*(1), 171-191.

Burger, J. M., & Palmer, M. L. (1992). Changes in and generalization of unrealistic optimism following experiences with stressful events: Reactions to the 1989 California earthquake. Personality and Social Psychology Bulletin, 18(1), 39-43.

Burns, W. J., & Slovic, P. (2012). Risk perception and behaviors: Anticipating and responding to crises. Risk Analysis.

Butler, C., & Pidgeon, N. (2011). From 'flood defence'to 'flood risk management': exploring governance, responsibility, and blame. Environment and Planning C: Government and Policy, 29(3), 533-547.

Calizaya, A., Meixner, O., Bengtsson, L., & Berndtsson, R. (2010). Multi-criteria decision analysis (MCDA) for integrated water resources management (IWRM) in the Lake Poopo Basin, Bolivia. Water resources management, 24(10), 2267-2289.

Canwest News Service. (2012, April 10). After a disastrous 2011, Que. farmers wonder what's in store for '12. *Canwest News Service*.

Canwest News Service. (2011, May 21). Residents near breaking point in flood-ravaged St-Jean, Que. *Canwest News Service*.

Carroll, B., Balogh, R., Morbey, H., & Araoz, G. (2010). Health and social impacts of a flood disaster: Responding to needs and implications for practice. *Disasters, 34*(4), 1045-1063. doi:10.1111/j.1467-7717.2010.01182.x

Carroll, B., Morbey, H., Balogh, R., & Araoz, G. (2009). Flooded homes, broken bonds, the meaning of home, psychological processes and their impact on psychological health in a disaster. *Health & Place, 15*(2), 540-547. doi:10.1016/j.healthplace.2008.08.009

Carone, M. T., Marincioni, F., & Romagnoli, F. (2018). Use of multi-criteria decision analysis to define social resilience to disaster: the case of the EU LIFE PRIMES project. Energy Procedia, 147, 166-174.

Center for Disease Control. (2018). Natural Disasters and Severe Weather. Retrieved from Center for Disease Control website: https://www.cdc.gov/disasters/mold/reenter.html

Chang, S. E., & Falit-Baiamonte, A. (2002). Disaster vulnerability of businesses in the 2001 nisqually earthquake. *Global Environmental Change Part B: Environmental Hazards, 4*(2), 59-71.

Cheng, C. T., Zhao, M. Y., Chau, K. W., & Wu, X. Y. (2006). Using genetic algorithm and TOPSIS for Xinanjiang model calibration with a single procedure. Journal of Hydrology, 316(1-4), 129-140.

Cloke, H. L., Pappenberger, F., Smith, P. J., & Wetterhall, F. (2017). How do I know if I've improved my continental scale flood early warning system?. *Environmental Research Letters*, *12*(4), 044006.

Cools, J., Innocenti, D., & O'Brien, S. (2016). Lessons from flood early warning systems. Environmental science & policy, 58, 117-122.

Cosens, B. (Ed.) (2012). *The columbia river treatey revisited: Transboundary river governance in the face of uncertainty*. Corvallis, OR: Oregon State University Press.

Cutter, S. L. (1996). Vulnerability to environmental hazards. *Progress in Human Geography, 20*(4), 529-539. doi:10.1177_030913259602000407

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global environmental change*, *18*(4), 598-606.

Cutter, S. L., Boruff, B. J., & Sirley, W. L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly*, 3639-3649.

Cutter, S. L., Burton, C. G., & Emrich, C. T. (2010). Disaster resilience indicators for benchmarking baseline conditions. *Journal of Homeland Security and Emergency Management, 7*(1). doi:10.2202/1547-7355.1732

De Dominicis, S., Fornara, F., Cancellieri, U. G., Twigger-Ross, C., & Bonaiuto, M. (2015). We are at risk, and so what? Place attachment, environmental risk perceptions and preventive coping behaviours. *Journal of Environmental Psychology*, *43*, 66-78.

Demeritt, D., Nobert, S., Cloke, H. L., & Pappenberger, F. (2013). The European Flood Alert System and the communication, perception, and use of ensemble predictions for operational flood risk management. Hydrological Processes, 27(1), 147-157.

Dodgson J, Spackman M, Pearman A, Phillips L. (2009) Multi-criteria Analysis: A Manual. Department for Communities and Local Government. Accessed 24 April 2012, via: http://www.communities.gov.uk/documents/corporate/pdf/1132618.pdf.

Dore, J., Lebel, L., & Molle, F. (2012). A framework for analysing transboundary water governance complexes, illustrated in the Mekong Region. *Journal of Hydrology*, *466*, 23-36.

Dottori, F., Szewczyk, W., Ciscar, J. C., Zhao, F., Alfieri, L., Hirabayashi, Y., ... & Feyen, L. (2018). Increased human and economic losses from river flooding with anthropogenic warming. Nature Climate Change, 8(9), 781-786.

Douben, N., & Ratnayake, R. (2006). *Characteristic data on river floods and flooding; facts and figures.* Paper presented at the J. Van Alphen, E. Van Beek, and M. Taal (edn.),

Floods, from Defence to Management, Third International Symposium on Flood Defence.

Drazkiewicz, A., Challies, E., & Newig, J. (2015). Public participation and local environmental planning: Testing factors influencing decision quality and implementation in four case studies from Germany. *Land use policy*, *46*, 211-222.

Eiser, J. R., Bostrom, A., Burton, I., Johnston, D. M., McClure, J., Paton, D., ... & White, M. P. (2012). Risk interpretation and action: A conceptual framework for responses to natural hazards. International Journal of Disaster Risk Reduction, 1, 5-16.

Elmer, F., Thieken, A. H., Pech, I., & Kreibich, H. (2010). Influence of flood frequency on residential building losses. *Natural Hazards and Earth System Sciences, 10*(10), 2145-2159.

Elmore, R. F. (1979). Backward mapping: Implementation research and policy decisions. *Political science quarterly*, *94*(4), 601-616.

Evers, M., Almoradie, A., & de Brito, M. M. (2018). Enhancing flood resilience through collaborative modelling and multi-criteria decision analysis (MCDA). In Urban Disaster Resilience and Security (pp. 221-236). Springer, Cham.

Fatemi, F., Ardalan, A., Aguirre, B., Mansouri, N., & Mohammadfam, I. (2017). Social vulnerability indicators in disasters: Findings from a systemic review. *International Journal of Disaster Risk Reduction, 22*, 219-227. doi:10.1016/j.ijdrr.2016.09.006

Fatti, C. E., & Patel, Z. (2013). Perceptions and responses to urban flood risk: Implications for climate governance in the South. *Applied Geography*, *36*, 13-22.

Fazey, I., Fazey, J. A., Fischer, J., Sherren, K., Warren, J., Noss, R. F., & Dovers, S. R. (2007). Adaptive capacity and learning to learn as leverage for social–ecological resilience. *Frontiers in Ecology and the Environment*, *5*(7), 375-380.

Feldman, D., Contreras, S., Karlin, B., Basolo, V., Matthew, R., Sanders, B., ... & Serrano, K. (2016). Communicating flood risk: Looking back and forward at traditional and social media outlets. International Journal of Disaster Risk Reduction, 15, 43-51.

Federal Emergency Management Agency. (2018). *Community Status Book Report*.

Federal Emergency Management Agency. (2018). Disasters. Retrieved from FEMA.gov website: https://www.fema.gov/disasters

Federal Emergency Management Agency. (2018). New York Severe Storms, Flooding, Tornadoes, andStraight-Line Wind (DR-1993). Retrieved October 30, 2018, from FEMA.gov website: https://www.fema.gov/disaster/1993

Federal Emergency Management Agency. (2018). Vermont Severe Storms and Flooding (DR-1995). Retrieved October 30, 2018, from FEMA.gov website: https://www.fema.gov/disaster/1995

Federal Emergency Management Agency. (2013). FEMA's Risk Mapping, Assessment, And Planning.

Fernandez, A., Black, J., Jones, M., Wilson, L., Salvador-Carulla, L., Astell-Burt, T., & Black, D. (2015). Flooding and mental health: A systematic mapping review. *PLoS ONE, 10*(4). doi:10.1371/journal.pone.0119929

Fewtrell, L., & Kay, D. (2007). An attempt to quantify the health impacts of flooding in the uk using and urban case study. *Journal of the Institute of Public Health, 122*, 446-451. doi:10.1016/j.puhe.2007.09.010

Floress, K., Akamani, K., Halvorsen, K. E., Kozich, A. T., & Davenport, M. (2015). The role of social science in successfully implementing watershed management strategies. *Journal of Contemporary Water Research & Education*, *154*(1), 85-105.

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global environmental change*, *16*(3), 253-267.

Garmestani, A. S., & Benson, M. H. (2013). A framework for resilience-based governance of social-ecological systems. *Ecology and Society*, *18*(1).

Gerber, B. J. (2007). Disaster management in the united states: Examining key political and policy challenges. *Policy Studies Journal, 35*(2), 227-238.

Golnaraghi, M. (Ed.). (2012). *Institutional partnerships in multi-hazard early warning systems: a compilation of seven national good practices and guiding principles*. Springer Science & Business Media.

Hansson, K., Danielson, M., & Ekenberg, L. (2008). A framework for evaluation of flood management strategies. *Journal of environmental management*, *86*(3), 465-480.

Hajkowicz, S., & Higgins, A. (2008). A comparison of multiple criteria analysis techniques for water resource management. *European journal of operational research*, *184*(1), 255-265.

Hartmann, T., & Driessen, P. (2017). The flood risk management plan: towards spatial water governance. Journal of Flood Risk Management, 10(2), 145-154.

He, Y., Wetterhall, F., Cloke, H. L., Pappenberger, F., Wilson, M., Freer, J., & McGregor, G. (2009). Tracking the uncertainty in flood alerts driven by grand ensemble weather predictions. *Meteorological Applications: A journal of forecasting, practical applications, training techniques and modelling*, *16*(1), 91-101.

Hellström, T. (2007). Critical infrastructure and systemic vulnerability: Towards a planning framework. *Safety Science, 45*(3), 415-430. doi:https://doi.org/10.1016/j.ssci.2006.07.007

Hermans, C., Erickson, J., Noordewier, T., Sheldon, A., & Kline, M. (2007). Collaborative environmental planning in river management: An application of multicriteria decision analysis in the White River Watershed in Vermont. Journal of Environmental Management, 84(4), 534-546.

Huitema, D., Mostert, E., Egas, W., Moellenkamp, S., Pahl-Wostl, C., & Yalcin, R. (2009). Adaptive water governance: assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda. *Ecology and society*, *14*(1).

International Joint Commission. (2020, March). *The Causes and Impacts of Past Floods in the Lake Champlain-Richelieu River Basin* (International Lake Champlain Richelieu River Study Board, Author).

Johnston, D. M., Lai, M. S. B. C. D., Houghton, B. F., & Paton, D. (1999). Volcanic hazard perceptions: comparative shifts in knowledge and risk. Disaster Prevention and Management: An International Journal.

Jones, E. C., Gupta, S. N., Murphy, A. D., & Norris, F. H. (2011). Inequality, socioeconomic status, and social support in post-disaster mental health in mexico. *Human Organization, 70*(1), 33-43. doi:10.17730/humo.70.1.4h340201207274qj

Kang, J.-L., Su, M.-D., & Chang, L.-F. (2005). Loss functions and framework for regional flood damage estimation in residential area. *Journal of Marine Science and Technology, 13*(3), 193-199.

Kellens, W., Terpstra, T., & De Maeyer, P. (2013). Perception and communication of flood risks: a systematic review of empirical research. Risk Analysis: An International Journal, 33(1), 24-49.

Kellens, W., Zaalberg, R., & De Maeyer, P. (2012). The informed society: An analysis of the public's information-seeking behavior regarding coastal flood risks. Risk Analysis: An International Journal, 32(8), 1369-1381.

Kick, E. L., Fraser, J. C., Fulkerson, G. M., McKinney, L. A., & De Vries, D. H. (2011). Repetitive flood victims and acceptance of FEMA mitigation offers: an analysis with community–system policy implications. *Disasters*, *35*(3), 510-539.

Kienzler, S., Pech, I., Kreibich, H., Müller, M., & Thieken, A. H. (2015). After the extreme flood in 2002: changes in preparedness, response and recovery of flood-affected

residents in Germany between 2005 and 2011. *Natural Hazards and Earth System Sciences*, *15*(3), 505-526.

Kunreuther, H., Ginsberg, R., Miller, L., Sagi, P., Slovic, P., Borkan, B., & Katz, N. (1978). *Disaster insurance protection: Public policy lessons*: Wiley New York.

Lebel, L., Anderies, J. M., Campbell, B., Folke, C., Hatfield-Dodds, S., Hughes, T. P., & Wilson, J. (2006). Governance and the capacity to manage resilience in regional social-ecological systems. *Ecology and Society*, *11*(1).

Lechowska, E. (2018). What determines flood risk perception? A review of factors of flood risk perception and relations between its basic elements. Natural Hazards, 94(3), 1341-1366.

Lendering, K. T., Sebastian, A., Jonkman, S. N., & Kok, M. (2018). Framework for assessing the performance of flood adaptation innovations using a risk-based approach. *Journal of Flood Risk Management*, e12485.

Lindell, M. K., Arlikatti, S., & Prater, C. S. (2009). Why people do what they do to protect against earthquake risk: Perceptions of hazard adjustment attributes. Risk Analysis: An International Journal, 29(8), 1072-1088.

Lindell, M. K., & Perry, R. W. (2000). Household adjustment to earthquake hazard: A review of research. Environment and behavior, 32(4), 461-501.

Lindell, M. K., & Whitney, D. J. (2000). Correlates of household seismic hazard adjustment adoption. Risk analysis, 20(1), 13-26.

Lodge, M. (2009). The public management of risk: The case for deliberating among worldviews. Review of Policy Research, 26(4), 395-408.

Lyles, L. W., Berke, P., & Smith, G. (2014). Do planners matter? Examining factors driving incorporation of land use approaches into hazard mitigation plans. *Journal of Environmental Planning and Management*, *57*(5), 792-811.

McClymont, K., Bedinger, M., Beevers, L. C., Walker, G., & Morrison, D. (2018). Analyzing city-scale resilience using a novel systems approach. In *Understanding Disaster Risk* (pp. 179-201). Elsevier.

Mears, D. K., & McKearnan, S. (2012). Rivers and resilience: Lessons learned from tropical storm irene. *Vt. J. Envtl. L., 14*, 177.

Meltsner, A. J. (1972). Political feasibility and policy analysis. *Public administration review*, 859-867.

Merz, B., Kreibich, H., Schwarze, R., & Thieken, A. (2010). Review article" assessment of economic flood damage". *Natural Hazards and Earth System Sciences, 10*(8), 1697-1724.

Merz, B., Kreibich, H., Thieken, A., & Schmidtke, R. (2004). Estimation uncertainty of direct monetary flood damage to buildings. *Natural Hazards and Earth System Science, 4*(1), 153-163.

Michel-Kerjan, E., & Kunreuther, H. (2011). Redesigning flood insurance. doi:10.1126/science.1202616

Michel-Kerjan, E. O. (2010). Catastrophe economics: The national flood insurance program. *Journal of Economic Perspectives, 24*(4), 165-186. doi:doi: 10.1257/jep.24.4.165

Mir, M. A., Ghazvinei, P. T., Sulaiman, N. M. N., Basri, N. E. A., Saheri, S., Mahmood, N. Z., ... & Aghamohammadi, N. (2016). Application of TOPSIS and VIKOR improved versions in a multi criteria decision analysis to develop an optimized municipal solid waste management model. Journal of environmental management, 166, 109-115.

Mochizuki, J., Schinko, T., & Hochrainer-Stigler, S. (2018). Mainstreaming of climate extreme risk into fiscal and budgetary planning: application of stochastic debt and disaster fund analysis in Austria. *Regional Environmental Change*, *18*(7), 2161-2172.

Moghadas, M., Asadzadeh, A., Vafeidis, A., Fekete, A., & Kötter, T. (2019). A multi-criteria approach for assessing urban flood resilience in Tehran, Iran. *International journal of disaster risk reduction*, *35*, 101069.

Moynihan, D. P. (2009). The response to hurricane Katrina. *International Risk Governance Council, Geneva, Switzerland*.

Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to environmental change: contributions of a resilience framework. *Annual review of Environment and Resources*, *32*.

Office of the New York State Comptroller. (2017, October). *Special Report: North Country Region Economic Profile*. State of New York.

Oladokun, V. O., & Montz, B. E. (2019). Towards measuring resilience of flood-prone communities: a conceptual framework.

Olsson, L., Jerneck, A., Thoren, H., Persson, J., & O'Byrne, D. (2015). Why resilience is unappealing to social science: Theoretical and empirical investigations of the scientific use of resilience. *Science advances*, *1*(4), e1400217.

Olsson, P., Gunderson, L. H., Carpenter, S. R., Ryan, P., Lebel, L., Folke, C., & Holling, C. S. (2006). Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems. *Ecology and society*, *11*(1).

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, *325*(5939), 419-422.

Özelkan, E. C., & Duckstein, L. (1996). Analysing water resources alternatives and handling criteria by multi criterion decision techniques. Journal of environmental management, 48(1), 69-96.

Pappenberger F, Cloke H L, Parker D J, Wetterhall F, Richardson D S and Thielen J (2015). The monetary benefit of early flood warnings in Europe Environ. Sci. Policy 51 278–9.

Pappenberger, F., Bartholmes, J., Thielen, J., Cloke, H. L., Buizza, R., & de Roo, A. (2008). New dimensions in early flood warning across the globe using grand-ensemble weather predictions. Geophysical Research Letters, 35(10).

Paranjothy, S., Kirrage, D., Wight, J., Baxter, T., Page, L., Rubin, G. J., . . . SR, P. (2011). Psychosocial impact of the summer 2007 floods in england. *BMC Public Health, 11*(1), 145.

Park, E., Scherer, C. W., & Glynn, C. J. (2001). Community involvement and risk perception at personal and societal levels. Health, Risk & Society, 3(3), 281-292.

Paton, D. (2008). Risk communication and natural hazard mitigation: how trust influences its effectiveness. International Journal of Global Environmental Issues, 8(1-2), 2-16.

Paton, D., Smith, L., & Johnston, D. M. (2000). Volcanic hazards: risk perception and preparedness. New Zealand Journal of Psychology, 29(2), 86.

Peek-Asa, C., Ramirez, M., Young, T., & Cao, Y. (2012). Flood-related work disruption and poor health outcomes among university students. *Prehospital and Disaster Medicine, 27*(6), 503-508. doi:10.1017/ S1049023X1200129X

Polasky, S., Carpenter, S. R., Folke, C., & Keeler, B. (2011). Decision-making under great uncertainty: environmental management in an era of global change. *Trends in ecology & evolution*, *26*(8), 398-404.

Public Safety Canada. (2018). Canada Disaster Database. Retrieved from Public Safety Canada website: http://cdd.publicsafety.gc.ca

Public Safety Canada. (2018). Disaster Financial Assistance Arrangements (DFAA). Retrieved October 30, 2018, from Public Safety Canada website: https://www.publicsafety.gc.c

Rahaman, M. M., & Varis, O. (2005). Integrated water resources management: evolution, prospects and future challenges. *Sustainability: science, practice and policy*, *1*(1), 15-21.

Ramos, M. H., Bartholmes, J., & Thielen-del Pozo, J. (2007). Development of decision support products based on ensemble forecasts in the European flood alert system. *Atmospheric Science Letters*, *8*(4), 113-119.

Renn, O. (2008). *Risk governance: coping with uncertainty in a complex world*. Earthscan.

Renn, O. (1998). The role of risk perception for risk management. Reliability Engineering & System Safety, 59(1), 49-62.

Resilience Alliance. (2018). *Panarchy*. https://www.resalliance.org/

Riboust, P., & Brissette, F. (2016). Analysis of Lake Champlain/Richelieu River's historical 2011 flood. *Canadian Water Resources Journal/Revue canadienne des ressources hydriques*, *41*(1-2), 174-185.

Rossa, A., Liechti, K., Zappa, M., Bruen, M., Germann, U., Haase, G., ... & Krahe, P. (2011). The COST 731 Action: A review on uncertainty propagation in advanced hydro-meteorological forecast systems. *Atmospheric Research*, *100*(2-3), 150-167.

Rözer, V., Müller, M., Bubeck, P., Kienzler, S., Thieken, A., Pech, I., ... & Kreibich, H. (2016). Coping with pluvial floods by private households. Water, 8(7), 304.

Sanderson, I. (2002). Evaluation, policy learning and evidence-based policy making. *Public administration*, *80*(1), 1-22.

Schanze, J. (2006). Flood risk management–a basic framework. In *Flood risk management: hazards, vulnerability and mitigation measures* (pp. 1-20). Springer, Dordrecht.

Schelfaut, K., Pannemans, B., Van der Craats, I., Krywkow, J., Mysiak, J., & Cools, J. (2011). Bringing flood resilience into practice: the FREEMAN project. *Environmental Science & Policy*, *14*(7), 825-833.

Siegrist, M., & Gutscher, H. (2006). Flooding risks: A comparison of lay people's perceptions and expert's assessments in switzerland. *Risk Analysis, 26*(4), 971-979. doi:doi:10.1111/j.1539-6924.2006.00792.x

Sjöberg, L. (2000). Factors in risk perception. Risk analysis, 20(1), 1-12.

Skodvin, T. (2007). Exploring the notion of political feasibility in environmental policy. *CICERO Working Paper*.

Slovic, P. (1987). Perception of risk. Science, 236(4799), 280-285.

Slovic, P., & Weber, E. U. (2002). Perception of risk posed by extreme events. Regulation of Toxic Substances and Hazardous Waste (2nd edition) Applegate, Gabba, Laitos, and Sachs, Editors), Foundation Press.

Smyth, R. L., Watzin, M. C., & Manning, R. E. (2009). Investigating public preferences for managing Lake Champlain using a choice experiment. Journal of Environmental Management, 90(1), 615-623.

State of New York. (2015, July). *Governor Cuomo Announces Economic Impact of Tourism Industry Exceeds $100 Billion For the First Time in New York State's History*.

State of Vermont. (2018). Flood Ready. Retrieved from State of Vermont website: https://floodready.vermont.gov

State of Vermont. (2011). *The Vermont Travel and Tourism Industry*. Retrieved from Tourism Research Center website: http://www.uvm.edu/tourismresearch/publications/Toursim_Industry_Fact_Sheet_2011.pdf

Stephens, E., & Bates, P. (2015). Assessing the reliability of probabilistic flood inundation model predictions. Hydrological Processes, 29(19), 4264-4283.

Tapsell, S. M., Penning-Rowsell, E. C., Tunstall, S. M., & Wilson, T. L. (2002). Vulnerability to flooding: Health and social dimensions. doi:10.1098/rsta.2002.1013

Thaler, T., & Levin-Keitel, M. (2016). Multi-level stakeholder engagement in flood risk management—A question of roles and power: Lessons from England. *Environmental Science & Policy*, *55*, 292-301.

Thielen, J., Bartholmes, J., Ramos, M. H., & Roo, A. D. (2009). The European flood alert system–part 1: concept and development. *Hydrology and Earth System Sciences*, *13*(2), 125-140.

Tierney, K. J. (1999, June). Toward a critical sociology of risk. In Sociological forum (Vol. 14, No. 2, pp. 215-242). Kluwer Academic Publishers-Plenum Publishers.

Tyler, T. R., & Cook, F. L. (1984). The mass media and judgments of risk: Distinguishing impact on personal and societal level judgments. Journal of Personality and Social Psychology, 47(4), 693.

UNISDR (2006). Developing Early Warning Systems: A Checklist. United Nations International Strategy for Disaster Reduction. EWC III Third International Conference on Early Warning. Available at: http://www.unisdr.org/2006/ppew/info-resources/ewc3/checklist/English.pdf

United Nations - Headquarters (UN). (2015). *Sendai Framework for Disaster Risk Reduction 2015-2030*.United Nations Office for Disaster Risk Reduction (UNDRR).

US Department of Commerce. (2012, April). *Vermont DR-4022 Economic Impact Assessment*.

Vermont Department of Labor, Economic & Labor Market Information. (2017). Labor Force and Unemployment in Vermont in 2011. Retrieved from Vermont Department of Labor, Economic & Labor Market Information website: http://www.vtlmi.info/Labforce.cfm?qperiodyear=2011&qareatype=01&qadjusted=Y

Vermont Emergency Management. (2018). National Flood Insurance Program. Retrieved from State of Vermont website: https://vem.vermont.gov

Vermont Futures Project. (n.d.). *Vermont Demographics*. Vermont Futures Project. https: //vtfuturesproject.org/vermonters-visitors/

Wachinger, G., Renn, O., Begg, C., & Kuhlicke, C. (2013). The risk perception paradox—implications for governance and communication of natural hazards. Risk analysis, 33(6), 1049-1065.

Walker, B., & Salt, D. (2012). *Resilience thinking: sustaining ecosystems and people in a changing world*. Island press.

Wang, J. J., Jing, Y. Y., Zhang, C. F., & Zhao, J. H. (2009). Review on multi-criteria decision analysis aid in sustainable energy decision-making. Renewable and sustainable energy reviews, 13(9), 2263-2278.

Werner, M., Cranston, M., Harrison, T., Whitfield, D., & Schellekens, J. (2009). Recent developments in operational flood forecasting in England, Wales and Scotland. *Meteorological Applications: A journal of forecasting, practical applications, training techniques and modelling*, *16*(1), 13-22.

Yang, T. H., Yang, S. C., Ho, J. Y., Lin, G. F., Hwang, G. D., & Lee, C. S. (2015). Flash flood warnings using the ensemble precipitation forecasting technique: A case study on forecasting floods in Taiwan caused by typhoons. Journal of Hydrology, 520, 367-378

Yoon, K. P., & Kim, W. K. (2017). The behavioral TOPSIS. Expert Systems with Applications, 89, 266-272.

Zia, A., Hirsch, P., Songorwa, A., Mutekanga, D. R., O'Connor, S., McShane, T., ... & Norton, B. (2011). Cross-scale value trade-offs in managing social-ecological systems: the politics of scale in Ruaha National Park, Tanzania. Ecology and Society, 16(4).

Zia, A., & Wagner, C. H. (2015). Mainstreaming early warning systems in development and planning processes: Multilevel implementation of Sendai framework in Indus and Sahel. *International Journal of Disaster Risk Science*, *6*(2), 189-199.

Zurich Flood Resilience Program. (2019). How to build an early warning system. Retrieved from Flood Resilience Portal website: https://floodresilience.net/how-to-build-an-early-warning-system

APPENDICES

APPENDIX A: HOUSEHOLD RISK PERCEPTION SURVEY

Introduction to Survey

We invite you to participate in a study regarding flood mitigation measures in the Lake Champlain Richelieu River Basin (where you live!), and collect your opinions regarding flooding in your community. This study is being conducted by Professor Christopher Koliba at the University of Vermont. We encourage everyone who receives this survey to participate, regardless of your background with flooding. Thank you in advance for your help.

Purpose
The purpose of this research is to learn more about how residents of the Lake Champlain Richelieu River Basin engage with the risk of flooding, and to learn about the way residents of the Lake Champlain Richelieu River Basin consider different potential solutions to flooding.

Study Procedures
If you take part in the study, you will be asked to answer a series of questions about the way you and your household perceive the danger of flooding, as well as your thoughts on different mitigation measures, and some questions about your demographics. Participation in this survey will take no longer than 30 minutes, and will be carried out online. Your participation in this survey is voluntary. We will not collect any identifiers, meaning the survey is completely anonymous.

Benefits
There is no direct benefit to you anticipated from participating in this survey. However, it is hoped that the information gained from your participation in this survey will contribute to the creation of flood mitigation measures that are in the best interest of community members and the environment. You may discontinue your participation in the survey at any time by closing the screen.

Risks
We will do our best to protect the information we collect from you during this study. We will not collect any information that will identify you to further protect your confidentiality and avoid any potential risk for an accidental breach of confidentiality.

Costs
There will be no costs to you for participation in this research study.

Compensation
You will not be paid for taking part in this study.

Confidentiality
All information collected about you during the course of this study will be stored with a code name or number so that we are able to match you to your answers.

Voluntary Participation/Withdrawal
Taking part in this study is voluntary. You are free to withdraw at any time. You may choose not to take part in this study, or if you decide to take part, you can change your mind later and withdraw from the study.

Participation
Your participation is voluntary, and you may refuse to participate without penalty or discrimination at any time.

Questions
The information above is only a brief summary of the study. If you are interested in learning more, please contact Emma Spett at emma.spett@uvm.edu or visit the study website at: https://www.ijc.org/en/lcrr.

You have been given and have read a summary of this research study. Should you have any further questions about the research, you may contact the person conducting the study: Emma Spett (201-566-6916; emma.spett@uvm.edu) or Christopher Koliba (802-656-3772; ckoliba@uvm.edu). Your participation is voluntary and you may refuse to participate or withdraw at any time without penalty or prejudice.

Thank you for taking the time to help us better understand these issues!

1. **Do you certify that you are 18 years of age or older, have read the above information and agree to take part in this research?**
   - o Yes
   - o No

2. **Please type your 5-digit zip code in the space provided below:**

3. **Have you experienced flooding at your current residence?**
   - o Yes, major flooding
   - o Yes, minor flooding
   - o No

4. **If you experienced flooding, please provide the years when flooding occurred:**

5. **If you experienced flooding, during any of these events, did you and/or any of your household members experience any of the following during or as a result of flooding? (Please check all that apply)**
   - o Loss of personal property/belongings
   - o Structural damage to residence
   - o Water damage to residence
   - o Evacuation from residence
   - o Loss of income
   - o Physical injury
   - o Mental health concerns (stress, anxiety, depression, PTSD, etc.)
   - o Long term health concerns (respiratory infections, toxic exposure, skin rash/infection, cancers, etc.)
   - o Other:

6. **I consider my community to be at risk of flooding:**
   - o Strongly agree
   - o Agree
   - o Neutral
   - o Disagree
   - o Strongly disagree
   - o I don't know

7. **I consider my home to be at risk of flooding:**
   - o Strongly agree
   - o Agree
   - o Neutral
   - o Disagree
   - o Strongly disagree
   - o I don't know

8. **Do you opt in to flood insurance?**
   - o Yes
   - o No
   - o I don't know

9. **If you opt in to flood insurance, what is your average annual premium?**
   - o $0-$200
   - o $201-$400
   - o $401-$600
   - o $601-$800
   - o $801-$1000
   - o $1001-$1200
   - o $1201-1400
   - o $1401-$1600
   - o More than $1600

10. **How far in advance do you typically hear about flooding in your community?**
    - o One week
    - o Three days
    - o One day
    - o Twelve hours
    - o Five hours
    - o One hour
    - o After the flood occurs
    - o I have never heard about flooding in my community

11. **What do you estimate is the likelihood that you will experience a flood at your home in the next ten years?**
    - o Very low
    - o Low
    - o Neither high nor low
    - o High
    - o Very high
    - o There is no chance of a flood
    - o I don't know

12. **Do you consider flooding when there is a heavy rainstorm?**
    - o Yes
    - o No

13. **Do you consider flooding when the snow melts in the spring?**
    - o Yes
    - o No

14. **Do you consider the risk of flooding when you buy a home?**
    - o Yes
    - o No

15. **How far is your home from a lake or river?**
    - o 0-1 miles
    - o 1-5 miles
    - o 5-10 miles
    - o More than 10 miles
    - o I don't know

16. **Is your home located in a flood zone?**
    - o Yes
    - o No
    - o I don't know

17. **If you do not live in a flood zone: How far do you live from a flood zone?**
    a. 0 to 1 miles
    b. 1 to 5 miles
    c. 5 to 10 miles
    d. More than 10 miles
    e. I don't know
18. **If you live in a flood zone: what is the designation of your home's flood zone?**
    - Moderate or low risk area (Zone B, Zone C, Zone X)
    - High risk area (Zone A, Zone AE, Zone A1-30, Zone AH, Zone AO, Zone AR, Zone A99)
    - Undetermined risk area (Zone D)
    - I don't know the designation of my home's flood zone
19. **In the past ten years, which, if any of the following problems have you experienced at your primary residence? (Please check all that apply)**
    - Flooding around property
    - Flooding on property
    - Basement flooding
    - Impacts to you/your family's health due to flooding
    - Flooding, erosion, or washouts of driveway or road to your house
    - Flooding, erosion, or washouts of roads in your community
    - Flooding to residences in my neighborhood/immediate surroundings
    - Other:
20. **Have you taken any of the following steps to protect your household from flooding? (Please check all that apply)**
    - Raised the foundation of my home
    - Landscaping for storm water management
    - Building flood walls
    - Placed sand bags prior or during a flooding event
    - Raised house onto stilts
    - Enrolled in the National Flood Insurance Program (For US program)
    - Keep sentimental belongings on upper floors
    - Sealed basement windows
    - Relocated critical systems (heating, electrical, hot water) from flood prone levels
    - Purchase private flood insurance
    - Nothing
    - Other:
21. **How would you rate your flood risk compared to your neighbors?**
    - I have an average flood risk
    - I have a higher than average flood risk
    - I have a lower than average flood risk
    - I have no risk of flooding
    - I don't know
22. **How much financial damage do you expect that a single flood would cause to your home and belongings?**
    - $0
    - $1-100
    - $101-1,000
    - $1,001-10,000
    - $10,001-$100,000
    - $100,001-1,000,000
    - More than $1,000,000
23. **How high do you estimate the probability that you or someone in your household will experience the following? Rate each possible event on a scale from 1 to 10, with 1 being impossible, and 10 being extremely likely.**

___My residence gets flooded, damaging property
___The roads around my home get damaged due to a flood, causing disruptions to my routine travel patterns
___I am laid off from my job
___I am injured in a car accident
___My house is burglarized
___My car is stolen
___I have a house fire
___A storm causes a power outage

24. **Please indicate the probability of you or someone in your household undertaking the following flood mitigation measures. Rate each measure on a scale from 1 to 10, with 1 being no probability ("I will never do this") and 10 being extremely high probability ("I will absolutely do this")**

___Support additional taxes to prevent flooding
___Contribute money for an early warning system to better prepare my household for floods
___Move to a safer region where flooding is not an issue
___Contribute money to recovery efforts after a flood
___Take measures to fortify my house against flooding
___Volunteer to assist in recovery efforts after a flood
___Take time to understand the best ways to mitigate the impacts of flooding
___Store dry goods and water in case of emergency

25. **Are you concerned about climate change?**
    - Yes
    - No
    - I don't know

26. What effect do you think climate change will have on flooding in your region? (Please check all that apply)

- o Flooding will become more frequent
- o Flooding will become more severe
- o Climate change will not affect flooding in my region
- o Flooding will become less frequent
- o Flooding will become less severe
- o I don't know
- o Other:

27. Addressing the issue of flooding requires the development of policies and programs meant to protect households, communities, and the environment. Please indicate how much you would be willing to pay for the following flood protection, in the form of government tax:

Flood mitigation measure	$0	$0-100	$101-500	$501-1000	$1001-5000	More than $5000
Reduce water levels during flooding events	☐	☐	☐	☐	☐	☐
Reduce flooding severity by storing or impeding the flow of water coming from contributing watersheds	☐	☐	☐	☐	☐	☐
Development of better response plans for emergency preparedness	☐	☐	☐	☐	☐	☐
Development of policy to better manage floodplains and adapt communities to flooding	☐	☐	☐	☐	☐	☐

28. Please note whether you agree or disagree with the below statements about flood mitigation:

Flood mitigation measure	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Government funds should be used to address flooding on private property	☐	☐	☐	☐	☐
Government funds should be used to reduce vulnerability before a flood	☐	☐	☐	☐	☐
Government funds should be used to help people repair damage after a flood	☐	☐	☐	☐	☐
Floodplain residents should be required to purchase insurance that would reimburse them for flood damage	☐	☐	☐	☐	☐
Flooding should be addressed by building projects that keep water away from development	☐	☐	☐	☐	☐
Flooding should be addressed by keeping development out of the floodplain	☐	☐	☐	☐	☐

29. In your opinion, does the benefit of living near the water outweigh the financial cost of flooding?

- o Yes
- o No
- o This does not apply to me
- o Other:

30. Have you ever had to stay home from work or school due to flooding?

- o Yes
- o No

31. **Imagine an activity you had planned (camping, hiking, boating, eating at a lakeside restaurant, etc.) is disrupted due to flooding. How are you most likely to react, as a consumer?**

- o I would cancel the activity
- o I would postpone the activity
- o I would do something else that has not been impacted by flooding
- o I would do the same activity in a nearby area not impacted by flooding
- o I would do the same activity in another region not affected by flooding
- o Other:

32. **Where do you get information about flood hazards? (Please select your top three)**

- o Neighbors and community members
- o Local fire/police
- o Twitter
- o Facebook
- o Instagram
- o Front Porch Forum or similar platform
- o Town/municipality website
- o Local television news
- o Local print news
- o Local radio
- o Scientific literature
- o Other:

33. **Who do you trust when getting information about flood hazards? (Please select your top three)**

- o Neighbors and community members
- o Local fire/police
- o Twitter
- o Facebook
- o Instagram
- o Front Porch Forum or similar platform
- o Town/municipality website
- o Local television news
- o Local print news
- o Local radio
- o Scientific literature
- o Other:

34. **Rank in order from 1 to 6 which of the following should bear the responsibility for flood management in your community (1 bears the most responsibility; 6 bears the least responsibility)**

___ The federal government

___ State government

___ Regional or county government

___ Local government

___ Non-governmental organizations

___ Individuals

35. **Below are a series of criteria that policymakers are using to consider what flood mitigation measures are best suited to the needs of the communities within the Lake Champlain and Richelieu River basin. Please rank order the following criteria from 1 to 9.**

Criteria	**Rank (1- most important to 9- least important)**
Reduce the financial cost of flood damages	
Reduce harm to economic activity due to flooding	
Reduce the number of homes that are impacted by flooding	
Reduce street closures due to flooding	
Reduce potential injury, stress, or loss of life due to flooding	
Reduce harm to vulnerable people due to flooding	
Maintain healthy ecosystems, including clean water and thriving biodiversity	
Prevent the spread of aquatic invasive species	
Reduce harm to historical and culturally sensitive sites due to flooding	

36. For each flood mitigation criteria, please check the box for your sense of the importance of the issue:

Criteria	Unsure	Not Important	Slightly Important	Moderately Important	Very Important
Reduce the financial cost of flood damages	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Reduce harm to economic activity due to flooding	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Reduce the number of homes that are impacted by flooding	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Reduce street closures due to flooding	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Reduce potential injury, stress, or loss of life due to flooding	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Reduce harm to vulnerable people due to flooding	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Maintain healthy ecosystems, including clean water and thriving biodiversity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Prevent the spread of aquatic invasive species	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Reduce harm to historical and culturally sensitive sites due to flooding	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

For questions 37-46, pick the answer that is more important to you:

37. Would you rather have a flood mitigation measure in place that:
- o Prioritizes the economic wellbeing of communities
- o Prioritizes the environmental health of our lake and river ecosystems

38. Would you rather have a flood mitigation measure in place that:
- o Prioritizes the economic wellbeing of communities
- o Prioritizes the health and wellbeing of community members

39. Would you rather have a flood mitigation measure in place that:
- o Prioritizes the economic wellbeing of communities
- o Prioritizes the protection of homes, roadways, and other infrastructure

40. Would you rather have a flood mitigation measure in place that:
- o Prioritizes the economic wellbeing of communities
- o Prioritizes the protection of historical and cultural sites in your community

41. Would you rather have a flood mitigation measure in place that:
- o Prioritizes the environmental health of our lake and river ecosystems
- o Prioritizes the health and wellbeing of community members

42. Would you rather have a flood mitigation measure in place that:
- o Prioritizes the environmental health of our lake and river ecosystems
- o Prioritizes the protection of homes, roadways, and other infrastructure

43. **Would you rather have a flood mitigation measure in place that:**
    - o Prioritizes the environmental health of our lake and river ecosystems
    - o Prioritizes the protection of historical and cultural sites in your community

44. **Would you rather have a flood mitigation measure in place that:**
    - o Prioritizes the health and wellbeing of community members
    - o Prioritizes the protection of homes, roadways, and other infrastructure

45. **Would you rather have a flood mitigation measure in place that:**
    - o Prioritizes the health and wellbeing of community members
    - o Prioritizes the protection of historical and cultural sites in your community

46. **Would you rather have a flood mitigation measure in place that:**
    - o Prioritizes the protection of homes, roadways, and other infrastructure
    - o Prioritizes the protection of historical and cultural sites in your community

---

47. **What type of residence do you live in?**
    - o Single family
    - o Multi-family
    - o Apartment
    - o Condominium
48. **Do you own or rent your home?**
    - o Own
    - o Rent
    - o I prefer not to answer
49. **How long have you lived in your current home?**
    - o Less than one year
    - o 1-5 years
    - o 6-10 years
    - o 11-15 years
    - o More than 15 years
50. **What is your gender?**

_____

51. **What year were you born?**

____ ____ ____ ____

52. **What is the highest level of education you have completed?**
    - o Less than 9th grade
    - o 9th grade to 12th grade, no diploma
    - o High school graduate (including GED)
    - o Some college, no degree
    - o Associates degree
    - o Bachelor's degree
    - o Graduate or professional degree
    - o Other:

53. **How many people live in your home?**

    [ ]

54. **How many people in your home are under the age of 18?**

    [ ]

55. **How many people in your home are over the age of 65?**

    [ ]

56. **What is your household income?**
    - o Less than $10,000
    - o $10,000 to $14,999
    - o $15,000 to $24,999
    - o $25,000 to 34,999
    - o $35,000 to $49,999
    - o $50,000 to $74,999
    - o $75,000 to $99,999
    - o $100,000 to $149,999
    - o $150,000 to $199,999
    - o $200,000 and up
    - o I'd rather not say
57. **What is your usual political ideology?**
    - o Consistently conservative
    - o Mostly conservative
    - o Mixed
    - o Mostly liberal
    - o Consistently liberal
    - o I'd rather not say
    - o Other:

Please feel free to include any additional comments in this space. Thank you for your participation